

Massachusetts Institute of Technology
Bulletin

Report of the President and the Chancellor Issue
1976-77



**Massachusetts Institute of Technology
Bulletin**

**Report of the President and the Chancellor Issue
1976-77**

Massachusetts Institute of Technology Bulletin
Volume 113, Number 4, November 1977

Published by the Massachusetts Institute of Technology
77 Massachusetts Avenue, Cambridge, Massachusetts 02139
five times yearly in August, September, October, November, and February
Second class postage paid at Boston, Massachusetts

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

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

The Massachusetts Institute of Technology admits students of any race, color, sex, religion, or national or ethnic origin to all rights, privileges, programs, and activities generally accorded or made available to students at the Institute. It does not discriminate against individuals on the basis of race, color, sex, religion, handicap, or national or ethnic origin in administration of its educational policies, admissions policies, scholarship and loan programs, and athletic and other school administered programs, but may favor US citizens or residents in admissions and financial aid.

The Institute has created and implemented and will continue to implement an affirmative action plan expressing its commitment to the principle of equal opportunity in education.

Corporation

Honorary Chairman: James R. Killian, Jr.
Chairman: Howard W. Johnson
President: Jerome B. Wiesner
Chancellor: Paul E. Gray
Treasurer: Glenn P. Strehle
Secretary: John J. Wilson

LIFE MEMBERS

Edward J. Hanley, John J. Wilson, James B. Fisk, George P. Gardner, Jr., Robert C. Gunness, Russell DeYoung, William B. Murphy, Laurance S. Rockefeller, Luis A. Ferré, Semon E. Knudsen, Robert B. Semple, Irénée du Pont, Jr., James R. Killian, Jr., John C. Haas, J. Kenneth Jamieson, George W. Thorn, Joseph J. Snyder, Paul M. Cook, Ralph Landau, Carl M. Mueller, Breene M. Kerr, Frank R. Milliken, Clint W. Murchison, Jr., Gregory Smith

MEMBERS

Angus N. MacDonald, Charles B. McCoy, Ellmore C. Patterson, Laurence Storch, James E. Turner, Edward O. Vetter, Louis W. Cabot, Frank T. Cary, Thomas F. Creamer, Edward E. David, Jr., Maurice F. Granville, Paul F. Hellmuth, Jerome H. Holland, Charles E. Reed, Cecily C. Selby, Richard L. Terrell, Jephtha H. Wade, Virgilio Barco, Shirley A. Jackson, Vernon E. Jordan, Jr., Norman B. Leventhal, Wilfred D. MacDonnell, Allan J. MacEachen, Harold J. Muckley, Mary F. Wagley, D. Reid Weedon, Jr., William J. Weisz, David R. Wilson, Ellis C. Littmann, William H. Mills, James A. Moody, Kenneth H. Olsen, Howard L. Richardson, Helen F. Whitaker, W. Gerald Austen, Yaichi Ayukawa, Vincent S. Castellano, David R. Clare, W. Van Alan Clark, Jr., Henry A. Hill, Charles G. Koch, Jerry McAfee, Denman K. McNear, F. Richard Meyer, III, David S. Saxon

PRESIDENT OF THE ALUMNI ASSOCIATION

Norman B. Leventhal

REPRESENTATIVES OF THE COMMONWEALTH

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

LIFE MEMBERS, EMERITI

Donald F. Carpenter, David A. Shepard, Walter J. Beadle, Irving W. Wilson, Thomas D. Cabot, Crawford H. Greenewalt, Lloyd D. Brace, William A. Coolidge, Ralph Lowell, Charles A. Thomas, Robert C. Sprague, Gwilym A. Price, James H. Doolittle, George J. Leness, Robert A. Lovett, Cecil H. Green, H. W. McCurdy, Julius A. Stratton

October 1, 1977

Contents

PRESIDENT AND CHANCELLOR	1
Statistics for the Year	20
Personnel Changes	26
DEAN FOR STUDENT AFFAIRS	39
Freshman Advisory Council	40
Undergraduate Seminar Program	42
Undesignated Sophomore Program	43
Office of Preprofessional Advising and Education	43
Minority Student Support	45
Women's Program	48
Advising and Counseling	49
Student Community Affairs, Student Activities, and Governance	51
Fraternities and Independent Living Groups	52
Institute Houses	54
Talbot House	57
Foreign Study Office	57
Department of Athletics	58
PROVOST	69
American Journal of Physics	70
Artificial Intelligence Laboratory	71
Center for Advanced Visual Studies (C.A.V.S.)	75
Cell Culture Center	78
Center for Cancer Research	79
Center for International Studies	80
Clinical Research Center	84
Committee on the Visual Arts (C.V.A.)	85
Division for Study and Research in Education (D.S.R.E.)	91
Harvard-M.I.T. Program in Health Sciences and Technology	95
Independent Activities Period (I.A.P.)	100
Joint Center for Urban Studies	102
Laboratory for Computer Science	112
Libraries	115
Lowell Institute School (L.I.S.)	124
Northeast Radio Observatory Corporation (NEROC)	
Haystack Observatory	125
Neurosciences Research Program (N.R.P.)	126
Operations Research Center	128
R.O.T.C. Programs	130
Sea Grant Program	131
Summer Session	136
Upward Bound Program	137
Wellesley-M.I.T. Exchange Program	139
Office of Minority Education (O.M.E.)	143

SCHOOL OF ARCHITECTURE AND PLANNING	149
Department of Architecture	155
Department of Urban Studies and Planning	159
Laboratory of Architecture and Planning	169
SCHOOL OF ENGINEERING	173
Department of Aeronautics and Astronautics	182
Department of Chemical Engineering	188
Department of Civil Engineering	196
Department of Electrical Engineering and Computer Science	201
Department of Materials Science and Engineering	207
Department of Mechanical Engineering	210
Department of Nuclear Engineering	221
Department of Ocean Engineering	225
Center for Advanced Engineering Study (C. A. E. S.)	229
Center for Policy Alternatives	236
Center for Transportation Studies (C. T. S.)	243
Innovation Center	249
Electric Power Systems Engineering Laboratory	250
SCHOOL OF HUMANITIES AND SOCIAL SCIENCE	253
Department of Economics	260
Department of Humanities	263
Department of Linguistics and Philosophy	277
Department of Political Science	279
Department of Psychology	284
SLOAN SCHOOL OF MANAGEMENT	289
SCHOOL OF SCIENCE	313
Department of Biology	316
Department of Chemistry	318
Department of Earth and Planetary Sciences	323
Department of Mathematics	328
Department of Meteorology	330
Department of Nutrition and Food Science	335
Department of Physics	339
Spectroscopy Laboratory	348
George R. Wallace, Jr. Astrophysical Observatory	351
VICE PRESIDENT AND DEAN OF THE GRADUATE SCHOOL	353
Medical Department	364
Registrar	372
OFFICE OF THE PRESIDENT AND THE CHANCELLOR	399
Council for the Arts	399
Information Processing Services (I. P. S.)	401
Institute Information Services (I. I. S.)	405
M. I. T. Press	414
Plasma Fusion Center	422

VICE PRESIDENT, ADMINISTRATION AND PERSONNEL	425
Office of Admissions	428
Office of the Advisor to Foreign Students	428
Office of the Educational Council	429
Career Planning and Placement Office	430
Student Financial Aid Office	431
Office of Personnel Development (O.P.D.)	432
Office of Personnel Relations	434
Office of Personnel Services	435
Affirmative Action Program	437
Office of Child Care	439
Office of Facilities Management Systems (O.F.M.S.)	441
VICE PRESIDENT, FINANCIAL OPERATIONS	443
Audit Division	443
Comptroller's Office	445
Lincoln Laboratory Fiscal Office	445
Office of Sponsored Programs (O.S.P.)	446
Office of the Director of Finance	448
VICE PRESIDENT, OPERATIONS	451
VICE PRESIDENT, RESEARCH	461
Francis Bitter National Magnet Laboratory	462
Center for Materials Science and Engineering (C.M.S.E.)	464
Center for Space Research	470
Detroit Institute of Technology-M.I.T. Association	473
Energy Laboratory	474
Laboratory for Nuclear Science (L.N.S.)	485
Nuclear Reactor Laboratory (N.R.L.)	488
Research Laboratory of Electronics (R.L.E.)	489
Undergraduate Research Opportunities Program (UROP)	497
Patent and Copyright Office	498
LINCOLN LABORATORY	501
VICE PRESIDENT, RESOURCE DEVELOPMENT	505
TREASURER OF THE CORPORATION	513
SECRETARY OF THE INSTITUTE	533
ALUMNI ASSOCIATION	539

President and Chancellor

Introduction: A Leadership Role

M.I.T. has always sought to exert leadership in its chosen fields, where it possesses unique strengths. Among the characteristics and resources that make this leadership role possible are M.I.T.'s spirit of innovation, its continuing commitment to addressing major technical and social problems of the day, the outstanding quality of its faculty and student body, the strong and substantive faculty and student linkages with government and industry, and the extraordinary dedication of M.I.T.'s friends and alumni. All of these encourage an independence which allows the Institute to act in most instances according to its own best judgment in a complex and increasingly constrained world. M.I.T. has been able, to a considerable degree, to select its own objectives and style, to create new ways to look at familiar problems, to understand and help solve new problems and, by embedding the education of students in the research enterprise, to provide a unique intellectual context to stimulate the minds of its students.

As we review the events of the past year we see many of those events as steps in the continuous evolution of M.I.T.'s educational programs and research priorities in response to emerging societal problems. We also note the emergence at M.I.T. of new organizational forms to foster educational and research efforts that transcend the boundaries of departments and schools. Academic disciplines, professions, and the educational programs related to both, go through periodic cycles of advancement and growth stimulated by challenging new discoveries, new organizing concepts, the availability of new technologies, and new social concerns. Such surges in a field are accompanied by rapid increases in student enrollments, research support, and the gravitation of researchers toward the new and exciting set of ideas. A university such as M.I.T. is a culture for such fields -- each at a different stage in the development of powerful new levels of understanding. In science, engineering, management, architecture, planning, the social sciences, and the humanities there is a continuous flow of new problems and of new efforts to understand and to solve them. The intellectual questions which most stimulate many M.I.T. faculty members and students are, increasingly, questions which require the collaboration of scholars from more than one discipline. Therefore, throughout the Institute there exists the need to find support for emerging new kinds of research, the need to invent new organizational forms which fit the new goals, and the need to articulate all of this with the educational program and continually to assess the adequacy of this program in a changing intellectual and social world. These are issues which have preoccupied many at M.I.T. in recent years and will continue to require much attention in the future.

While we have sought to maintain the intellectual vigor of M.I.T.'s departments and research centers and to provide resources and encouragement for their continued evolution and renewal, we have also been concerned to broaden and deepen the financial base on which M.I.T. rests. Thus it gives us considerable satisfaction to note that the Leadership Campaign has passed the half-way point toward the goal of \$225 million. At the same time we realize that the hardest half of the Campaign is ahead of us, and we are prepared to redouble our efforts to meet the ultimate goal. We are also pleased to report that M.I.T. was able to operate with an essentially balanced budget during the past year, due not only to increased revenues from the Campaign and other sources, but equally to the effective cost-control measures exercised during the past five years. Fiscal problems have demanded much administrative energy during the last five years and obviously must continue to do so. Fund raising and ensuring effective use of available funds are critical to the survival of M.I.T. as a high-quality private institution.

In this Report we will discuss a number of issues concerning the kind of education M.I.T. provides for its undergraduates, the ways in which the evolution of educational and research programs reflect major contemporary concerns in our society, the several new organizational forms which are developing at M.I.T. to support work which faculty members and students want to do, and the way in which all of these intersect with the need to maintain the financial strength of the Institute.

Issues in Undergraduate Education

Undergraduate education is a primary mission of the Institute and an essential part of the close partnership between education and research that is the Institute's most distinctive and characteristic feature. From time to time in these Reports, we have noted significant developments and directions in undergraduate education at M.I.T. We have commented on the range of student interests and the diversity of the Institute's formal programs; on the recruitment, support, and contributions of minority students and women students; on the Institute's desire to increase the relevance of its educational experience to the fundamental societal problems of our time and to the eventual solution of those problems; and on the increasingly central part that direct research experience for students plays in the Institute's undergraduate programs. In all these respects, and in others as well, one may note the continuing emergence of the Institute as a major university in the fullest and broadest sense of Dr. James R. Killian, Jr.'s prescriptive phrase, "a university polarized around science, technology, and the arts."

Undergraduate education at M.I.T., with its balance of science, technology, social concerns, and humanistic studies, continues to be popular among the most talented young people in our nation; the Class of 1981 is larger than planned at 1,080 members. The policy of modest increases in class size, which we have been implementing during the past few years, is now straining the capacity of the housing system and creating serious shortages of financial aid. There are more students who are qualified to come to M.I.T., who want to come, and whom we could responsibly educate, than we can house or for whom we can provide needed financial aid. These two needs will receive special attention during the second half of the Campaign. Furthermore, once here, undergraduates select their field of concentration according to their own interests, and in recent years we have noted resurgent interest in the various fields of engineering. This interest continues to grow -- last year 63 percent of all "designated" second-year students were enrolled in the School of Engineering, a continuation of a pattern which showed 45 percent in 1974-75 and 55 percent in 1975-76. Such large shifts in undergraduate enrollment, particularly into the Departments of Chemical Engineering, Electrical Engineering and Computer Science, and Mechanical Engineering, combined with budget reductions taken as part of our Institute-wide cost control efforts over the past five years, have produced stresses which must be relieved.

While increases and shifts in enrollment create a variety of such strains, they equally attest to the high regard with which an M.I.T. education is held by the world at large, and they remind us of our obligation to ensure that an M.I.T. education is the best of its kind. During a period of increasing concern about the goals and forms of undergraduate education in colleges and universities throughout the nation, M.I.T. faculty members have continued to demonstrate their own deep commitment to undergraduate education, and we believe that a new look at these questions of goals and forms will be a major part of faculty discussion and planning in the next several years.

The Institute's undergraduate programs are distinctive among those of comparable universities in that they are professionally oriented in format. At the same time, the faculty has developed and instituted a set of requirements for breadth and diversity within each student's program, so that an M.I.T. undergraduate program may be a truly liberal education. In this Report, we turn to three fundamental aspects of our undergraduate programs. The first concerns the extent and

form in which the Institute provides an introduction to the basic natural sciences and the adequacy of this introduction as a foundation for upperclass departmental work. The second concerns the way in which the Institute requires, or provides opportunities for, undergraduate work in the humanities, arts, and social sciences. This issue is of keen interest because M.I.T. has always sought to incorporate a significant humanistic component in its undergraduate education and the desire for this has grown stronger in recent years as the interactions between science, technology, and the society have become more intense and controversial. The third concerns the form and content of undergraduate engineering education, which has been the subject of intense review by the Committee on Engineering Education of the School of Engineering, a study group that has been functioning for the past two years.

I

The Institute's undergraduate degree requirements include a required year of elementary calculus, a year of physics, and a half-year of chemistry or biology. These constitute the "science core requirement," and the subjects satisfying this requirement are normally taken in the freshman year. In addition, students must satisfy a three-subject science distribution requirement; a laboratory requirement; a set of humanities, arts, and social sciences requirements; the program requirements of their majors; and a physical education requirement. (It is interesting to note that the combined science core, science distribution, and laboratory requirement are the equivalent of a science major at most universities.) It is the "science core" which concerns us here, and its evolution over the years in response to a changing intellectual world.

In the years immediately following World War II, and in the light of the Report (now nearly 30 years old) of the Committee on Educational Survey, the faculty reformulated the previous science core requirement for all undergraduates to include four terms of mathematics, four terms of physics, and two terms of chemistry, to be taken in the first and second years. Specific subjects to satisfy the requirement were offered by each of the three departments. The Committee had noted M.I.T.'s prior history of rigidly prescribed educational programs and was striving toward somewhat more flexibility in order best to develop the talents of its students. Nonetheless, the programs of freshmen and sophomores remained largely uniform, and this helped to provide a sense of common educational experience and purpose among first and second year students.

The science core requirement of the 1950s was established in the belief that all undergraduates should have a serious professional introduction to the basic sciences, that this introduction should be taught by professionals in those sciences, that determination of content should largely rest with those professionals, but that, at the same time, the core subjects should represent a reasonably well-planned common body of scientific knowledge and skills upon which upperclass departmental programs could later rely and draw.

Early in the 1960s, after the Sputnik shock, pressures of two kinds led to a reexamination and revision of the science core requirement. First, increasing numbers of freshmen had, in high school, gone more deeply than before into significant portions of the M.I.T. core material. Second, the faculty increasingly came to believe that a larger amount of choice, through which students could obtain programs more closely fitted to their individual backgrounds and interests, would be educationally desirable. The Committee on Curriculum Content Planning, established by President Julius A. Stratton, recommended in 1964 that the amount of common core time in all three departments be reduced by 50 percent, and that some of the time thereby gained in a student's schedule be assigned to a new Science Distribution Requirement. This recommendation was adopted by the faculty, and the general structure of the core requirement has remained unchanged since that time.

During the past decade, the faculty has introduced certain additional options within the science core. The student may choose either of two one-year sequences for the year of mathematics, and any of four one-year sequences for the year of physics. The differences in content among these alternative sequences are less than might at first appear. Both mathematics sequences cover elementary calculus and elementary vector analysis. All physics sequences cover mechanics

in the first term and electricity and magnetism in the second term. The differences that do exist among alternatives are differences of choice and emphasis in illustrative examples and, to some extent, differences of intellectual and teaching styles. The required term of chemistry, on the other hand, has evolved into a required term of chemistry or biology, and five distinct alternatives have been designated by the faculty. These include: a subject in elementary chemical structure and bonding, a subject in structure and bonding emphasizing organic chemistry, a subject in physical chemistry, a subject in chemical structure emphasizing the solid state and taught by the Department of Materials Science and Engineering, and a subject in basic biology taught by the Department of Biology.

The functions of the science core in a student's undergraduate program are several. First, the science core provides a common body of knowledge and methods, and a level of proficiency in them, that can be assumed by all departments for upperclass work. Most undergraduate degrees from M.I.T. specify a professional field, and departments in the Schools of Engineering and Science have justified this specification in part on the basis that the degree represents a coherent four-year program in the specified field, of which the science core is the foundation. At the same time, the present articulation between the science core and the possible upperclass departmental majors permits the student a full range of choices among possible majors at the end of the freshman year. The student is not forced to make this choice at the time of entering M. I. T.

Second, in addition to serving as a form of prerequisite for later work, each subject in the science core provides an introduction, in its own right, to its own disciplinary area. The argument that substantive knowledge of each of these areas is an essential part of an education for today's and tomorrow's world is strong.

Third, the core subjects emphasize creative analytical ability of a high order. For example, passage through the physics subjects, even for some of our most talented undergraduates, is not always easy. The challenge of analyzing and solving a complex "word problem," of developing a sense of the potential intersection and interaction of theoretical concept and practical reality, and of developing a confidence in one's own powers for such analysis, is difficult but ultimately valuable and instructive. This is perhaps best summed up in the proud observation of many graduates that "M. I. T. taught me how to think."

Not everyone agrees that the science core, in principle or in detail, is desirable. Some argue that the core subjects represent a significant and somewhat arbitrary hurdle in the undergraduate curriculum that may discourage talented students from coming to M. I. T. and from contributing to the richness and variety that should characterize a great university. They go on to argue that there are forms of thought and sensibility that are creative, demanding, and valuable, but are unrelated to the concepts and methods of the natural sciences as presented in the core. They observe that some departmental programs outside of engineering and science do not need the subject matter of the core as a prerequisite. Finally, some would take the further position that the analytical abilities emphasized in the core are not easily transferable to disciplines outside of the natural sciences and engineering.

Some others at the Institute hold that the science core has shrunk too much and that its reduction by half in 1964 was mistaken. They believe that the educational benefits of the core would be enhanced by enlarging it and that, moreover, the identification of M. I. T. with depth and strength in science and technology, which they believe to be of great value to the Institute and to society, was weakened by the 1964 modifications.

Still others are concerned that the achievements and abilities of students entering the upperclass departmental programs appear to be more uneven than before. This leads to concern for ways in which the core subjects in the freshman year could better recognize and remedy the deficiencies in skill and prior preparation. It also leads to more general questions concerning the better identification of abilities and disabilities among entering students, the difference in educational style and context between secondary school and university, and the variety of learning styles that students may bring to their work at M. I. T.

We expect that the status and content of the science core will be a subject of faculty deliberation during the next several years. While we do not know what the outcome of such discussions will be, we do not anticipate that a reduction in the size of the present science core will occur or that a change in its standard of difficulty will be recommended. We expect, rather, that possible and desirable changes in content and emphasis within the science core subjects will be a principal object of discussion and that much of that discussion will be focused in the relevant departments. Issues of content may include the following: Do the present core subjects place too much emphasis on getting a single correct numerical answer rather than on the qualitative solutions and approximation bounds that are more characteristic of scientific and engineering applications? Do the core subjects adequately recognize the role and power of computers in current science and engineering? Are the present core subjects, especially in mathematics and physics, justified in emphasizing continuous and deterministic concepts and methods in the spirit of Newton and Euler at the expense of the often more discrete and statistical concepts of 20th Century science? Can one emphasize the latter in introductory subjects without at the same time sacrificing a significant measure of internal coherence and hence of educational value? Can one make such changes and maintain the paradigm of hard and creative analysis that the present subjects appear to present? Is the current core material a necessary prerequisite to a proper and sensitive understanding of more recent concepts and methods? We believe that the Institute will look forward with the liveliest interest to these discussions and to their outcome.

II

We turn next to the question of the manner and extent to which the Institute can provide a truly liberal education for its undergraduate students. We believe that for M. I. T., such an education should ideally have four characteristics. First, it should provide a capability for careful intellectual analysis and creative intellectual effort, both qualitative and quantitative, with a recognition of the power of new concepts and insights to make such analysis and such effort fruitful. Second, it should develop the capacity for intellectual self-renewal, so that students can continue to learn and to cope with new problems. Third, it should encourage and help to provide a personal, social, and cultural breadth that enables students better to relate to and understand their society, their world, and their past. Fourth, it should provide through knowledge, example, and encouragement, a basis upon which students may best build and maintain personal integrity and a sense of commitment to their highest personal values. We believe that M. I. T. students should find some elements of these qualities in every area of study -- science, technology, social science, humanities, and the arts.

Science and technology have been criticized for their lack of concern with values, and it is sometimes alleged that this lack of concern on the part of scientists and engineers has been a cause of current environmental, economic, and social problems. We do not accept this view. Science and technology have always had a strong relationship to, and indeed been a manifestation of, the values -- and often the best values -- of the society and culture in which they find themselves. We believe that in the 116 years of its existence M. I. T. has been extraordinarily successful in training its students for roles of leadership and service in our society, and that it has done so in accord with the highest hopes and aspirations of its time. The problem today is not that science and technology have been separated from questions of value, but that the problems which our society faces have become more complex and contemporary values more pluralistic. The challenge that we face is one of matching our resources and strengths as an institution to society's needs and goals in appropriate ways.

Therefore, we do not believe that it is the principal role of the humanities, arts, and social sciences in a liberal education to serve as the repository for "values" or as the vehicle through which values are transmitted or inculcated. For us, the humanities, arts, and social sciences have a primary educational role that is two-fold. First, they introduce the student to forms of culture, and to attitudes and sensibilities that are not only of interest and reward in their own right, but also help the student to think about, understand, and relate to other human beings and to society. Second, they provide the student with new conceptual dimensions for understanding and participating in the life of our time.

In the spring of 1974 the faculty approved a new form for the undergraduate humanities requirement, which is now called the Institute Requirement in the Humanities, Arts, and Social Sciences. This requirement continues to consist of eight half-year subjects, but now includes a distribution requirement in a range of areas, a small core of concentration in one aspect of humanities, the arts, or social sciences, and several electives. The new arrangement provides students with a broader range of choices in the freshman and sophomore years and has reduced the load on the few subjects that formerly were allowed to satisfy the Humanities Requirement.

There is continuing interest among the faculty with regard to the Requirement in the Humanities, Arts, and Social Sciences. Issues on which opinion varies include: the amount of diversity and choice there should be in the list of subjects approved for this requirement; the desirability of a return to a more limited set of offerings, perhaps to unique offerings, to satisfy some part of this requirement; the appropriateness of present criteria for distribution and concentration within the requirements; and approaches to teaching writing at the Institute. We note here that the issue of a writing program has been a significant matter for faculty discussion during this year.

Writing subjects have been part of an M.I.T. education since the early days of the Institute, although instruction has taken different forms as student needs and interests have evolved over the years. During the past five years there has been a growing concern with the need to help M.I.T. students improve their writing skills, a concern which has parallels in many other colleges and universities. Since the abilities, experience, and needs of M.I.T. students vary widely, what seems to be needed is not a single required "Freshman English" subject but rather a variety of subjects from which students can choose. A popular subject called "Writing and Experience" was developed on an experimental basis in 1972, and by 1974 had evolved into a Pilot Writing Program having at its core several subjects in the Department of Humanities, but also including subjects in other departments, cooperative instruction in technical subjects in four Schools, workshops of many kinds, editorial conferences, thesis writing seminars, and informal seminars on writing open to the entire M.I.T. community. The philosophy of education which underlay many of these activities developed, over the years, into a fairly coherent set of values and goals which appeared to be at variance with the philosophy and goals of other parts of the Department of Humanities concerned with teaching literature and writing. The educational philosophy of the Pilot Writing Program was designed to be supportive of a student's attempts to write, and "non-judgmental" in discussing student work. Critics of the Pilot Writing Program argued for greater attention to formal structure and style in the written piece.

In the spring of 1975 the Dean of Humanities appointed a committee of M.I.T. faculty members and outside advisors to recommend a course of action. The Committee submitted its report in June 1976, and we noted its major recommendations in last year's Report and anticipated a year of discussion throughout the Institute. The Committee's Report contained an analysis of the writing needs of M.I.T. students and of the context of writing instruction at M.I.T. and at other universities, and it evaluated the extent to which the Pilot Writing Program appeared to be achieving its own goals and to be meeting the writing needs of M.I.T. The Report included a wide range of educational and administrative recommendations, the thrust of which was to endorse a variety of approaches for integrating writing into the M.I.T. undergraduate education, including but not limited to that associated with the Pilot Writing Program. For example, the Report recommended that new subjects in expository writing, science writing, and technical writing be established; that writing be emphasized in subjects given throughout the Institute; and that a Resource Center offering diagnostic and tutorial services be established. The Report also recommended administrative arrangements for the support of a permanent writing program.

Unfortunately, some members of the Pilot Writing Program and their students (and even some alumni) who had developed a strong sense of commitment to the style of teaching developed in the Pilot Writing Program, interpreted actions taken to implement the recommendations as an effort, not of support and growth, but of opposition to the Pilot Program's goals and even existence. In May, the faculty held a broad-ranging discussion of the educational and policy issues involved. At this time, the intent of the Committee's recommendations and the actions to implement them taken by the Dean of the School of Humanities and Social Science were clarified and supported.

The problem of writing at M.I.T. is now being addressed directly and on a broad front. All faculty share the desire that M.I.T. students write better so that they will be able to play a more valuable role in society and to express their own individuality with greater ease and satisfaction. The School of Humanities and Social Science is working hard to develop a permanent Writing Program which will achieve these objectives, although we expect that it will take several years to develop a fully articulated program that meets the diverse range of needs which have been identified.

III

Turning now to the School of Engineering we encounter an organization besieged by new-found popularity and a faculty hard at work adapting its educational programs to new technical challenges, heavy student loads, and the results of ongoing financial limitations.

During the "engineering science" era, the linkages between the School and the practice of engineering in many industries weakened, although strong relations continued with industrial research laboratories. During the past decade, as the School substantially increased its emphasis on the development of technology and its use in the engineering process, existing relations with the practicing professions and industry were greatly strengthened and new relations built. The motivation is obvious: The School of Engineering must not only relate to the foundations of engineering -- that is to the engineering sciences -- but it must also relate to the practice of engineering as a profession. This transition to a more balanced perspective was accomplished through the desire of both faculty members and students to study broader applied problems, coupled with a growing interest in synthesis and design.

In previous years, we have reported on a self-appraisal project in the School of Engineering that focused particularly on efforts to improve the quality of some educational offerings and at the same time eliminate some undesirable overlap. A Committee on Engineering Education (C. E. E.) was created in the fall of 1975 as an outgrowth of that School-wide self-appraisal project. It had become apparent that a broad-based, major review of the entire educational program in the School should be undertaken. The particular factors that made the review timely included external pressures such as the changing role of engineers in society, the changing character and direction of research support, and the changing social and political environment in which engineering is practiced.

In October 1976 the C. E. E. issued a comprehensive progress report which included a statement of Goals for Engineering Education at M.I.T. to serve as a foundation for the School's programs. These goals incorporate the commitments which the School's educational programs have to students, the society at large, the engineering professions, and to the Institute. The Committee considered appropriate academic programs and environments for undergraduate and graduate engineering education, developing a set of guidelines for the future planning of educational innovations which can serve as a basis for a broader discussion of undergraduate education.

The Committee concluded that there are subjects, at both the undergraduate and graduate level, which are of interest to more than one department in the School of Engineering but which it is difficult for individual departments to develop due to personnel and budget limitations. Examples of such subjects include:

- service subjects to students, such as computer programming;
- subjects of common interest but not central to a departmental program, such as entrepreneurship or innovation;
- subjects that integrate knowledge from several disciplines and are conducive to synthesizing this knowledge, such as design subjects;
- subjects at the interface between engineering and other professions, such as those which involve aspects of economics, law, and management.

The Committee on Engineering Education is arranging with the appropriate Institute faculty committees plans for conducting a three-year experiment in creating, offering, and evaluating School-wide subjects.

Most of the engineering sciences such as thermodynamics, structural mechanics, fluid dynamics, etc. are part of the core curriculum in most engineering departments. Although there are gaps and overlaps in the subject offerings at each level, each department has a unique perspective on the discipline and quite naturally desires to retain its own special version. The School has begun to bring together faculty members from different engineering departments to form "area committees." These committees are ad hoc in nature and meet to consider such issues as the scheduling of similar subjects to provide students with optimum flexibility, improvement of the advisory system to students in the area, the adequacy of the existing range of subjects, and new curriculum development directions. Another proposed activity of these area committees will be to develop School-wide undergraduate laboratories. Over the years many undergraduate laboratory facilities have deteriorated. The cost of acquiring and maintaining up-to-date equipment is too high for most departments to support excellent undergraduate labs. The area committees can help faculty to plan, staff, operate, and maintain interdepartmental labs for the benefit of all departments.

We share with the School of Engineering the goal of continuous evolution of educational programs and streamlining where appropriate. We are aware of the resource limitations which make these processes difficult for the School and expect to give this problem particular attention in the coming years.

Evolving Academic Forms

As we examine the activities of M. I. T. over the past five years, a striking feature is the increasing permeability of the boundaries between departments and between Schools. In both research activities and educational programs, groups of people form around mutual interests, creating a network of activities which may cut across traditional organizational lines. Through these working relations they invent new ways for the Institute to address particularly complex and challenging intellectual issues.

Such developments have been part of the M. I. T. tradition for many years. For example, the Research Laboratory of Electronics, established immediately after World War II, set a style in interdisciplinary and interdepartmental research that was influential on this campus and nationwide. We have reported annually on recent M. I. T. activities in such areas -- in the field of energy (which we will discuss in detail later in this Report); in the Division for Study and Research in Education; in various activities of the Schools of Engineering and Management; in our varied efforts to address the issues of humanity, technology and society; and in the wide range of health-related activities which have grown up at M. I. T. during the past decade. Work in the last two areas has now progressed to the point that new organizational forms seem needed to foster their continued development. In the past year we have reached the decision to establish a College of Health Sciences, Technology and Management, and to work toward the establishment of a College of Science, Technology and Society. Our use of the term "College" for these two efforts comes from the sense of the word "collegium" -- a group of colleagues -- and is intended to describe a group of educational and research activities which transcend the concerns of any single department, School, center or laboratory, but which are present in many of them. That is, the designation "College" is being used for the first time in the history of M. I. T. to designate an academic entity that has its roots in several Schools and that involves not only research but also educational programs having a broad common focus (such as health) developed jointly by members of the faculty from several departments.

I

The College of Health Sciences, Technology and Management

Over the past decade research in the sciences of health and life has been increasing at M. I. T. until it now comprises nearly one-third of the Institute's research effort and is carried out in all five of M. I. T. 's Schools and in numerous interdepartmental laboratories and centers. We have reported several times on various aspects of this growth and this year will discuss several new developments involving the Harvard-M. I. T. Joint Program in Health Sciences and Technology; the establishment of an M. I. T. College of Health Sciences, Technology and Management; and a new physical facility which is to house important components of these activities along with the M. I. T. Medical Department.

During its seven-year history, the Harvard-M. I. T. Joint Program in Health Sciences and Technology has developed educational programs to train physicians having special skills in the physical, engineering, and other quantitative sciences; and graduate programs for engineers and scientists in medical engineering and medical physics. These are people who are needed if modern science and technology are to diffuse rapidly, responsibly, and economically into medicine and are to have a broad impact on human health. The Joint Program has also fostered the growth of major research projects in which multidisciplinary teams of physical scientists, physicians, and engineers are participating and is encouraging the organization of medical engineering departments in hospitals affiliated with Harvard. As intended, these activities have significantly expanded the opportunities for collaborative research, helping to bring together the complementary resources, interests, and talents of faculty and students at both Harvard Medical School and M. I. T.

While this program was developing it became clear that other M. I. T. faculty members and students were developing strong interests in health-related fields which were not particularly appropriate for cooperation with Harvard academic units. During this period many purely M. I. T. activities developed for which the aegis of the Joint Program was not fully appropriate. As the scope of such activities grew it became obvious that it was desirable to find a way, somewhat independent of the Joint Program, to facilitate these and other efforts in both education and research. We have also felt that there would be great benefit from consolidating some of them in a common, centrally-located physical facility.

During the past year it has become possible to solve several of these problems at once.

a. When the Joint Program in Health Sciences and Technology was established it had been agreed that some \$10 million in new endowment would be needed to support M. I. T. 's and Harvard's permanent commitment to the endeavor. This year the funding goal has virtually been reached, the program has amply justified our hopes for it, and therefore the Executive Committee of the M. I. T. Corporation and the Harvard Board of Overseers approved its permanent establishment as a jointly governed Division of Health Sciences and Technology. This inter-institutional status transcends that of research units such as the Harvard-M. I. T. Joint Center for Urban Studies, in that the Division will be able to sponsor degree programs and selective faculty appointments, in addition to conducting joint research projects.

b. The development of the Joint Program in Health Sciences and Technology has been greatly assisted by the Health Sciences Fund, an independent, non-profit organization established in 1974 by Uncas A. Whitaker to provide support for research projects in the life sciences and biomedical engineering. The Fund has initially supported students at M. I. T. and at the Harvard Medical School who are engaged in thesis research, and faculty members at both institutions, primarily junior but not exclusively so, who are initiating research projects. Though the Fund has not limited its support to students and faculty associated with the Joint Program, a significant part of its \$500,000 annual funding has supported Program-related work.

c. We have been most fortunate in the past few months to have achieved the support of the Whitaker Foundation and the Pew Memorial Trust for the construction of new physical

facilities to house many of M. I. T. 's health-related research and educational activities, and the M. I. T. Medical Department. This opportunity has made it possible to establish a College of Health Sciences, Technology and Management. The health-related activities to be brought together in the College transcend the concerns of any single department, laboratory, center or School, but are present in many of them. Among the educational and research programs that will be developed under the college umbrella will be the areas of human biology, physiology, and experimental medicine; the area of Health Services Planning and Management; the M. I. T. components of the Harvard-M. I. T. Division of Health Sciences and Technology, including the new doctoral programs in medical engineering and medical physics. The College will serve as an integrating focus for much but not all of M. I. T. 's health-related work that does not involve Harvard units. It is anticipated that practically all of the College's faculty will hold joint appointments in one of the five Schools, that subjects and academic programs will be developed jointly with the relevant departments and schools and that students will be enrolled in the various departments of M. I. T.

d. One of the most exciting features of the physical plans for housing much of M. I. T. 's health-related work is the possibility of having in the same complex both the new College of Health Sciences, Technology and Management and the M. I. T. Medical Department which began as a typical college health service but over several decades has become a large multi-specialty group practice. This year, the staff of 24 full-time and 38 part-time physicians and 202 other professional support personnel cared for some 25,000 patients who made more than 115,000 visits to the Department. The Department assumes responsibility for the complete health care of our 8,500 students under the student health plan and for some 1,500 of our students' dependents who opt to receive their care in the Department. Since 1933, as an employee benefit, the Department has also offered free ambulatory primary care to our employees, and some 5,000 M. I. T. and Draper Laboratory employees currently take advantage of this privilege.

In 1973 the Medical Department established the M. I. T. Health Plan, a comprehensive, pre-paid medical care program. The M. I. T. Health Plan, organized in cooperation with Blue Cross and Blue Shield of Massachusetts, is one of three programs in the nation organized by university health services to offer a full range of pre-paid health care services to employees, and is the only program offered by a university without a medical school. (Yale and Harvard offer similar programs.) Membership in the Plan was initially limited to 1,000 employees and their dependents but high levels of patient and physician satisfaction and favorable cost experience during this pilot phase resulted in our decision to open enrollment in July 1975. The membership has grown at approximately the predicted rate of 1,000 members per year, and the current projection of steady state is some 12,500 members, or some 38 percent of those eligible.

By serving the entire M. I. T. community, the Medical Department has been able to develop programs and services which could not be supported within the economic framework and scale of a health service limited only to students. More importantly, this diversity has enabled the Department to attract a highly skilled and concerned professional staff, thus assuring high quality medical care for students as well as other patients.

While the Medical Department's primary purpose is delivery of medical care, there exists a great interest and enthusiasm among the staff for collaborative efforts in teaching and research with academic departments and laboratories at the Institute. The medical staff has sought innovative approaches to the delivery of high-quality health care services in such areas as extensive use of people other than physicians to provide some kinds of health care, psychiatry, uses of intermediate care inpatient programs, and development of pre-paid methods of organizing and financing the delivery of medical care. The staff has provided joint thesis supervision for students engaged in thesis work and other academic projects, and has provided a patient data base for research projects conducted by faculty members and students.

The expansion both in the spectrum of services delivered and the population served has had the inevitable -- and foreseen -- effect on the Medical Department's space requirements. Present facilities are inadequate by virtue of size, plan, and construction to accommodate even current services. The construction of a new health-related facility will not only provide badly needed and modern space for the Medical Department, but will do so as an integral part of a project which will house the new College of Health Sciences, Technology and Management. The Institute will, of course, proceed through normal channels to request and obtain the Certificate of Need for health service facilities required by Federal and state law prior to initiating construction.

We confidently predict that new and mutually productive relationships among M.I.T. faculty and staff in health fields will benefit both those whose primary mission is service and those whose primary missions are teaching and research. The College of Health Sciences, Technology and Management represents a major commitment by M.I.T. to apply its resources and proven strengths toward improving the health of our nation and the quality of its health care. The next few years should thus be exciting ones for all of us.

II

Toward a College of Science, Technology and Society

We described last year, in noting the 25th anniversary of the establishment of the School of Humanities and Social Science, the long-standing concern M.I.T. has had that technological and societal problems are so inextricably interwoven that their relationship should be an explicit subject for research and education at M.I.T. In the past few years there have been a wide range of activities throughout the Institute addressed to this issue, among them a study group initiated by the School of Humanities and Social Science to develop a way by which a measure of convergence of the humanistic and technological streams of the Institute could be attained. From the work of this group, after discussion with a substantial number of faculty members, there emerged a proposal to develop a new entity within M.I.T. tentatively to be called the College of Science, Technology and Society, having a faculty and a fellowship of scholars drawn from many disciplines and departments, an undergraduate teaching program, a research center, and an organization to support continuing study groups addressing themselves to selected contemporary problems. The proposal for the College, in the form of a prospectus which grew out of several years of thought and discussion, has been circulated to the M.I.T. Faculty Council for discussion and has been submitted to potential donors.

The intellectual purposes of the College are clear: the findings of science and the applications of engineering are now so directly engaged in the workings of society that professional education for scientists and engineers must include the study of ways in which scientific, technological, social and human elements interact to give shape to society; and the study of such interactions should be done explicitly through the investigation of problems in modern society which are produced by the interaction. The primary concerns of the College -- concerns about the nature, power, and limits of scientific thought; about the interaction between science and social institutions; about the relationship between technological innovations and the quality of the human and natural environments; and about living in modern society -- are a fundamental and integrated part of the lives of scientists and engineers at M.I.T. There is, within M.I.T., a great deal of information, the product of both research and experience, about the way in which the interactions of scientific, technological, and social factors determine the shape of modern life. This information and experience is of different kinds and is now, ordinarily, contained in different departments, Schools, and centers. We believe that much of this diverse evidence could acquire deeper meaning and contribute to further understanding of certain aspects of modern society if it could be brought into new combinations and fitted together in more extensive relationships. There is no conflict between the new effort and the many policy-oriented programs at M.I.T. and elsewhere, for the focus of the College would be on the humanistic aspects of technological society -- its culture, the lives of its people, their attitudes, perceptions, problems, goals, and prospects. It would seek to be an integrative cultural force on the campus.

The purpose of the College will be to supply a means that does not now exist to develop the requisite activities. The need therefore is to develop an institutional form which will provide a base sufficiently secure to maintain the integrity of the effort while supplying the direct connections with Schools and departments necessary to ensure the performance of the desired integrative function.

The most difficult question with regard to the administrative structure of the new entity is its prospective relationship to the various Schools in which related work is currently under way. It was initially proposed that the College be independent of the five Schools, but after much discussion and in view of concerns that emerged among some members of the faculty, we have concluded that the program should be started and operated in association with the School of Humanities and Social Science, from which it grew. This will not only establish a clear relationship between the College and the School, but will also allow the program to start more quickly and efficiently. We expect that support adequate to the program's initial needs will be obtained in the fall of 1977, and that further support will be obtainable as the program grows. We expect that the coming year will see this new enterprise getting effectively started.

Fields in Flux

As we noted at the beginning of this Report, M.I.T. is a culture for research and educational activities which are constantly evolving. This, combined with changes in secondary schooling, requires a periodic reassessment of the efficacy of our undergraduate programs, as we discussed earlier. Occasionally, it also leads to the development of new organizational forms such as the colleges in order to most effectively match the potential of growing faculty and student interests with the needs of society.

But most of M.I.T.'s work is done within the familiar structure of departments, Schools, laboratories and centers where there is a comparable ebb and flow of stimulating new ideas, programs, and educational activities. The Institute's intellectual health and vitality depend on the development of these new activities which capture the imagination of students and faculty and which provide stimulation and new perspectives for ongoing programs. Support of such activities represents investment in the Institute's intellectual capital and, as they develop, new sources of recurring financial support often open up. M.I.T.'s ability to create programs in which government, industrial, and university interests can come together around shared concerns creates a remarkably productive context for success. But in the beginning many of these efforts are critically dependent on the foresight of private supporters.

I

An excellent example of this phenomenon is the Energy Laboratory which we have reported on each year since its establishment in 1972. Laboratory projects now involve 60 Energy Laboratory staff members, 70 faculty members, and 150 students from various departments in all five M.I.T. Schools, especially from the School of Engineering and the Sloan School of Management. The Laboratory has become a major source of support for faculty and students in these Schools. The annual funding for the Laboratory has grown to over \$7 million, of which \$450,000 are discretionary funds contributed largely by corporate partners to support the development of projects in new research areas. While the Energy Laboratory, at its founding five years ago, was well ahead of the Federal government's capacity to fund either basic or applied research in the energy area, private organizations, particularly in industry, recognized the need and supported its initial efforts. Gradually an appropriate balance between public and private support is being attained.

In order to increase the nation's capability to establish effective energy policies, this year the Energy Laboratory, building on its well-established energy policy group, developed an

M. I. T. Center for Energy Policy Research as a context for collective effort by industry, labor, public interest groups, government, and other universities, to focus on long-term energy policy. The main objectives of the Center are: 1) to build up the resource base of technically competent, comprehensive studies of important issues in the energy area; 2) to use this analysis to support the preparation of papers on individual policy issues directed towards operating executives, government officials, and the informed public; and 3) to support these policy studies with an improved foundation of data and research results on fundamental areas of energy economics, technology, and management. Invitations to join the Center's advisory board have been extended to an initial group of organizations with the insistence that a commitment to intense professional interaction and collaboration is a vital aspect of participation. Emphasis is being given to diversity of participants and sponsors to help ensure the objectivity and credibility of the work. The response to the establishment of this Center has been overwhelmingly positive, and its financial support is growing steadily. (It is of interest to note that the Energy Research and Development Administration (ERDA) has not yet been able to support policy research so private support for the Energy Policy Center is essential.)

The foresight of the Laboratory's early supporters is being confirmed. Because of their early commitment the Institute has been able to build a Laboratory unique in its range of activities and especially in the depth of its analytic capability which served as a national resource before most people were aware of an "energy crisis," and is now a substantial contributor to its understanding.

II

Equally exciting and promising was the establishment last year of a Plasma Fusion Center to serve as an intellectual and administrative focus for work in plasma physics and fusion. This move was made desirable by the growing level of activity in the plasma field as a result of the highly successful operations of the initial experiments on the M. I. T. fusion machine, Alcator, which has subsequently produced the highest level of performance so far achieved in such a device. In addition to the work on confinement conducted on Alcator at the Francis Bitter National Magnet Laboratory, at M. I. T. there are strong complementary programs presently under way in plasma confinement theory, experimental plasma research, conceptual studies on future fusion power plants, and research in basic technologies of critical importance to fusion power. Major objectives of the new Center will be to develop a successor machine to Alcator, capable of even better performance, and to better relate work on the Alcator machines with other theoretical and experimental work at the Institute.

While the majority of work in plasma and fusion has been supported by a combination of National Science Foundation, ERDA, and M. I. T. funds, there came a point last year when timely industrial support was responsible for the continued progress of the M. I. T. effort. A much more powerful generator was needed to drive the new Alcator C, but no appropriate equipment budget could support the cost. After some inquiry it was discovered that Consolidated Edison in New York was retiring a suitable 200 megawatt generator and was willing to make it available to M. I. T. So, in the very near future a generator which has given years of reliable service to a public utility will be serving as the basic component of the power supply for advanced thermonuclear research at M. I. T.

III

During the past decade the School of Engineering as a whole has found considerable intellectual stimulation from its increasing collaboration with industry. During a decade in which the School substantially increased its emphasis on the development of technology and its use in the engineering process, previously strong links between engineering and the sciences were balanced by joint interest on the part of both M. I. T. and a number of industries in more applied problems. The Energy Laboratory involves a large number of faculty members and students from the School of Engineering in such activities. The Polymer Processing Program, which we have mentioned in previous years, now has an industrially sponsored research volume exceeding \$300,000 per year and recently a similar program in ceramics was started by the Department of Materials Science and Engineering.

Contemporary challenges across a wide range of industries in the areas of manufacturing and productivity are also of interest to the School of Engineering. Major advances, particularly those involving the sophisticated use of computers, will require the combined commitment of industry, labor, universities, and government, and to this end the School has established a Laboratory for Manufacturing and Productivity hoping to draw faculty and students from many departments and Schools of the Institute committed to working with industry, labor, and government on the development of new manufacturing technologies and systems.

To further strengthen the association between the Institute and the engineering professions in industry and to provide for our students educational opportunities which do not exist on campus, the School this year established an Engineering Internship Program, incorporating the important elements of cooperative education into a combined S. B. -S. M. program. This program, which involves all departments of the School, provides not only new opportunities for students, but also opportunities for faculty to work more closely with engineers in industry and for industry to keep abreast of research progress at M. I. T.

As we mentioned earlier in this Report, undergraduate and graduate enrollments in engineering at M. I. T. have been increasing rapidly during the past three years, reversing the decline experienced in the late 1960s and early 1970s. Further increases in undergraduate engineering enrollments appear highly likely over the next two years. These rapid growths, combined with growth in the volume of research conducted in the School, have created substantial overloads on a faculty whose size has remained constant. It is essential that we provide new resources to support these higher levels of activity and we propose to establish a special development fund for the School of Engineering within the current Leadership Campaign. This fund would primarily support the expansion of the faculty through the addition of a number of assistant professors, but would also support curriculum development activities and provide resources for the School to develop new uses of computers and television in teaching, provide seed funds for new, cooperative research projects, and enable the School to invest in equipment needed for new areas of education and research.

IV

A quite different area which is just on the brink of a major breakthrough in the opinion of many, is our understanding of how the human mind works. For over 25 years there has been intensive interest and activity at M. I. T. in a range of topics that traditionally would have been designated "study of the brain and mind." Work on these topics has included investigations in cybernetics, the communications sciences, the computer sciences, and theory of information processing, whose intellectual roots go back to the pre-World War II work of Norbert Wiener. Neurophysiology, learning, vision, psycholinguistics, and the study of cognition have been major areas of interest for the Department of Psychology since its establishment in 1964. Linguistics and philosophy, too, have drawn closer to these issues in recent years. Inquiry into this range of questions has brought together electrical engineers, computer scientists, neurophysiologists, biologists, psycholinguists, linguists, philosophers, and mathematicians. People from these diverse disciplines are focusing on a common goal -- to understand the structure, organization, and function of mental processes, their role in the causation of human behavior, their physical basis, and their growth in the individual and the species. These fields are currently in a state of rapid development largely because of new modes of conceptualizing the issues. The simultaneous achievement of conceptual, theoretical, and experimental advances has endowed old interests with new vigor. The result has been a major liberation of scientific imagination, occurring at M. I. T. and elsewhere.

Faculty members from M. I. T. 's Department of Linguistics and Philosophy, Psychology, and Electrical Engineering and Computer Science, with support from the Alfred P. Sloan Foundation, will lead a visiting scientist program and a series of major workshops in the cognitive area during the next two years with the goal of developing a more precise sense of the most promising lines of inquiry. We are encouraged that it has been possible to find support at a critical stage in the development of what could be a major new intellectual field, and are confident that as it develops momentum and reaches the stage where new organizational and funding mechanisms would be appropriate, they will become available.

V

As we noted earlier in this Report, research and training in fields related to health have been steadily growing over the past decade. This growth has been particularly significant in the fields of basic and applied biology, where an intellectual revolution took off from the discovery in 1953 of the structure of DNA, which signaled the beginning of an era in molecular biology. M.I.T. faculty members in this area have been most distinguished contributors.

The life sciences reflect the areas of basic scientific inquiry where practical applications are most often readily apparent to the general public. This is in part a source of their great strength; the desire to improve the nation's health care doubtlessly explains why Federal research support has continued at a high level during a period when many other fields of science experienced declines. Yet the very success of the life sciences has given rise to special problems. One acute concern is that of the scientists' ethical responsibility to the wider public -- most vividly illustrated by the case of recombinant DNA research, which involves the splicing of different genes.

This year M.I.T. was involved in a great deal of discussion of the responsibility of the scientist and the development of new arrangements to provide safe conditions for this research at M.I.T. The National Institutes of Health (NIH) Guidelines for Recombinant DNA Research were published in June 1976, just at the time that the Mayor and City Council of Cambridge had become aware of Harvard's plans to build a so-called P-3 laboratory to carry out recombinant DNA experiments. M.I.T. had a laboratory of this type in the Center for Cancer Research which, after some small modifications, was certified by an M.I.T. committee as satisfying the NIH requirements. In July 1976, the Cambridge City Council passed a three-month "good faith" moratorium on P-3 recombinant DNA experiments in the City of Cambridge. This moratorium was later extended for another three months so that a citizen group appointed by the City Manager could study the situation and make recommendations to the City Council.

The six-month delay in using M.I.T.'s laboratory caused considerable frustration, but during that period members of both the M.I.T. faculty and administration cooperated intensively with the City Council and the citizen review board. In January, this board recommended unanimously that P-3 recombinant DNA experiments could go on in Cambridge if certain precautions in addition to those in the NIH Guidelines were taken. Experiments of this type were carried out at M.I.T. during the spring term.

Local challenges to recombinant DNA research have since been springing up in many university communities. In addition, the issue has moved to the national level where numerous members of Congress have proposed legislation for supervising such research. The effort on the part of scientists to prevent precedent-making restrictions and regulations continues at this time. It might be a short step from control of DNA research to limitations in other fields. Undoubtedly, in the years to come, we will hear more frequent arguments to restrict research in some fields of science.

In recognition of the seriousness of this issue the group involved in planning the College of Science, Technology and Society has been holding a seminar entitled "Limits to Inquiry" which may develop into a continuing study group. We look forward to continuing these discussions, for a civilization which limits its inquiry out of fear of what it might learn will soon stifle both its intellectual life and its social development. The issues are major ones but the goal is to find ways to discuss them throughout the society and to manage the consequences of new knowledge, not to cut off its source.

Summing Up

M.I.T. is an extraordinary place with a proud heritage of service and a vibrancy unmatched anywhere -- firmly rooted in its dedication to science and technology for the benefit of humanity. Its achievements are fundamentally the achievements of individuals working together toward shared goals. In this Report we have tried to share our view of M.I.T.'s problems and opportunities in the mid-1970s. A primary goal of this administration has been not only to encourage and support the efforts of faculty members and students in developing new intellectual fields and modes of education appropriate to M.I.T.'s leadership role in our society, but to do so in such a way that the financial base on which the Institute rests is strengthened. Only in this way can M.I.T.'s programs be resilient to shifts in national mood and erratic economic conditions; and, equally important, only in this way can we underwrite the Institute's independence and the creative initiatives which keep it strong. Our efforts in this regard have been of two kinds -- to maintain fiscal control in an economic era which is highly problematic for institutions of higher education, and to increase the private sources of support on which M.I.T.'s independence depends through the Leadership Campaign. We are pleased to report significant progress on both fronts.

In our Report of a year ago we spoke of progress toward elimination of the Institute's operating deficit and of our two fiscal goals for the next few years. The first goal was to bring operating expenses and normal operating revenues closer towards balance so that there would be no call on capital in the form of funds functioning as endowment, and so that we would be less dependent on current unrestricted gifts for the support of operations. This objective is important because we must, except in brief periods of adjustment to major financial discontinuities such as those of 1973-74, set aside each year for capital purposes some portion of that year's receipts of unrestricted gifts.

The past year evidenced encouraging progress toward this goal. The year closed with revenues, including unrestricted gifts, in nominal balance with expenses (the precise deficit was \$126,000, an amount less than 0.05 percent of the expense budget). This essential elimination of the operating deficit was achieved a year earlier than we anticipated as a result of increases in current gifts -- an outcome attributable to the Leadership Campaign, improvements in reimbursement from research sponsors for the indirect costs of research, increases in revenues associated with the growth of the Industrial Liaison Program, and close attention to cost control by those responsible for expenditures at the Institute.

We anticipate that the operating budget will balance again during the current year, and expect as well, to make some progress during the next three years toward the goal of making some portion of current unrestricted gifts available for capital purposes, including additions to funds functioning as endowment.

Our second goal, as stated a year ago, is to achieve a balance between the rates of growth of expenses and of revenues so that the financial state of the Institute is more stable. While progress has been made toward this objective, the problem is highly refractory, and dynamic balance remains an unachieved objective, progress toward which is critically dependent upon the level of inflation in the economy, continued growth in gift support of Institute operations, and further improvements in the annual rate of growth of investment income.

One aspect of the financial management of the Institute during the past year deserves special mention. In an effort to provide better continuity and to encourage a somewhat longer planning horizon, last year we prepared budgets for a two-year period. While the plans for 1978-79 were, of necessity, more tentative and less detailed than those for the current year, the longer look at programs, needs, and opportunities was, we believe, welcomed by all who participated in the process. As we move into budget making this year, reviewing and making precise the budget plans for 1978-79 enunciated nearly a year ago, we plan to add another year to the planning cycle.

A particularly important and rewarding part of the two-year planning process was a series of meetings with individual department heads and associated deans for the purpose of reviewing departmental programs, intellectual issues and concerns, and resource needs for the near term. These meetings left us with both a clarified picture of the fundamental intellectual and academic framework of the Institute, and a sense of the extraordinary quality and vitality of the 23 academic departments.

In May, slightly more than two years into the five-year M.I.T. Leadership Campaign, we had passed the halfway mark to the target of \$225 million with pledges and receipts in excess of \$130 million. As we mentioned earlier, we are gratified by this success but by no means complacent because we expect the second half of the Campaign to be more difficult than the first. Not only are we once again facing a lackluster economy and tax legislation discouraging to philanthropy, but to a considerable extent our first-half accomplishment was made possible by strong support from those individuals and corporations closest to M.I.T. This is not to say that we are discouraged, rather that we are preparing to work harder during the second half of the Leadership Campaign and we anticipate that the M.I.T. Corporation will join us in this surge.

Three members of the Corporation have joined Howard W. Johnson in the direction of the Campaign. Edward O. Vetter and W.B. Murphy have become Co-Chairmen (with Paul F. Hellmuth) of the Campaign to assist in the direction of the drive and in solicitation. Richard L. Terrell is heading our new National Business Committee of alumni and friends to assist in developing support for M.I.T. in the industrial community.

The Industrial Liaison Program and the Associates Program continued to grow during the year, and the additional income these programs provided played a very significant role in the improvement of the financial situation of the Institute. Many other results of the Campaign have had a very positive effect on our operations. In particular these include the 17 endowed professorships and faculty development chairs, and the anonymous gifts of the \$800,000 in matching funds which helped raise the Alumni Fund to a record high of \$4.8 million. We especially note two magnificent capital gifts: The generosity of the Whitaker Foundation and the New York Community Trust which pledged gifts of \$10 million, and the Pew Memorial Trust which provided \$9 million, have made possible the proposed health sciences and health services facilities described earlier. Plans for construction are proceeding.

During the next year three major projects will be given special emphasis -- a \$10 million development fund for the School of Engineering; the \$5 million needed to complete the funding for the Athletic and Special Events Center; and \$6.5 million for the Visual Arts Facility which is the first part of a three-phase program to provide satisfactory work and study space for faculty and students engaged in the creative arts. The plan for the facility calls for three units to house the three major program components -- visual arts including film and video, music, and drama. A challenge gift of \$1.5 million has been pledged to begin the campaign for this facility.

We close our Report this year with a feeling of continuing pride in the privilege of being associated with M.I.T. The activities and achievements described in this Report are the result of very hard work on the part of thousands of people, each of whom has contributed time, energy, and above all concern on behalf of M.I.T. The years ahead will be full ones as we continue to address the major issues which are inevitable for an organization intent on being first-rate, creative, and relevant to contemporary society. We look forward to the challenge.

IN SPECIAL RECOGNITION

The individual efforts and distinctions on the part of the faculty at M.I.T. have been many during the past year. Four members of the faculty were elected to membership in the National Academy of Sciences; six were elected to the National Academy of Engineering; and four were elected to membership in the American Academy of Arts and Sciences. Samuel C. C. Ting, the first Thomas Dudley Cabot Professor, was honored as co-recipient of the Nobel Prize in Physics. Professor Ting was cited "for pioneering work in the discovery of a heavy elementary particle of a new kind."

Of special note during the year was the selection by the faculty of Dr. Robert M. Solow, Institute Professor and Professor of Economics, as the fifth recipient of the James R. Killian, Jr., Faculty Achievement Award.

The past year saw several changes in senior posts that deserve special mention. Professor Alan A. Altshuler was appointed Head of the Department of Political Science; Professor Gene M. Brown, Head of the Department of Biology; Professor Mildred Dresselhaus, Director of the Center for Materials Science and Engineering; Professor Richard Held, Head of the Department of Psychology; Professor Albert G. Hill, Director of the Plasma Fusion Center; Professor Arthur K. Kerman, Director of the Center for Theoretical Physics; Professor Samuel J. Keyser, Head of the Department of Linguistics and Philosophy; Professor Edward N. Lorenz, Head of the Department of Meteorology; Walter E. Morrow, Head of the Lincoln Laboratory, succeeding Dr. Gerald P. Dinneen who has been appointed Assistant Secretary of Defense; Dr. Melvin Rodman, Director of the Medical Department; and Dr. James Wei, Head of the Department of Chemical Engineering. Dr. Robert I. Hulsizer, Jr., Professor of Physics, began his term as Chairman of the Faculty.

We wish especially to note the decision of Professor Alfred A. H. Keil to resign as Dean of the School of Engineering effective August 31, 1977. Dean Keil will spend his time working with the Center for Policy Alternatives, the Energy Laboratory, and the prospective College of Science, Technology and Society. Dean Keil has given distinguished leadership to the School during a period in which the nature of engineering practice, and thus engineering education, have changed significantly. Dr. James D. Bruce, Associate Dean of Engineering, will assume full responsibility in the Office of the Dean until a successor to Dean Keil has been designated.

The past year also marked the retirement of eight distinguished members of the faculty. Their years of service to the Institute and to their students will long be remembered. They are: Professor Michael B. Bever, Department of Materials Science and Engineering; Institute Professor Morris Cohen, Department of Materials Science and Engineering; Professor Bernard S. Gould, Department of Biology; Professor S. Neal Hartley, Department of Humanities and Institute Archivist; Professor Patrick M. Hurley, Department of Earth and Planetary Sciences; Professor J. Francis Reintjes, Department of Electrical Engineering and Computer Science; Professor John C. Sheehan, Department of Chemistry; and Professor Clark C. Stevenson, Department of Chemistry.

Of particular sadness to us during the year were the untimely deaths of several respected colleagues.

Carolyn B. Cox, Director of the Registry of Guests, died in July 1976. A member of the M. I. T. community for 30 years, Mrs. Cox became Director of the Registry of Guests in 1960, providing support to foreign visitors to the Institute. In addition, she was responsible for arranging M. I. T.'s representation at ceremonies of other universities and for many years served as executive secretary to the Committee on Commencement. Her services to the Institute were characterized by their extraordinary grace and sensitivity.

President and Chancellor

Leicester F. Hamilton, Professor of Analytical Chemistry Emeritus, died in December 1976. A member of the faculty for 43 years, Professor Hamilton showed great devotion to generations of M.I.T. students and was extraordinarily active in guiding their development as young adults.

Thomas M. Hill, Professor of Management and Associate Dean of the Sloan School of Management, died in March 1977 after a long illness. A member of the M.I.T. faculty for 31 years, Professor Hill had done extensive work in managerial and financial accounting theory. During his long career at the Sloan School he had a substantial influence on the development of many of its major programs.

James Holt, Professor of Mechanical Engineering Emeritus, died in August 1976. A member of the M.I.T. community for 40 years, Professor Holt was a specialist in heat engineering and repeatedly filled administrative posts in the Department of Mechanical Engineering in times of need.

Frank M. Lewis, Professor of Marine Engineering Emeritus, died in October 1976. Although he retired from the faculty in 1960 after a career of 43 years, Professor Lewis remained at the Institute as a productive and creative researcher until a year before his death. He was widely known for his contributions to the knowledge of torsional vibration, ship vibration, and propeller performance.

Jeffrey L. Pressman, Associate Professor of Political Science, died suddenly in March 1977 at the age of 33. Professor Pressman was widely regarded as the leading young scholar of American politics in this country. He engaged the intellect of his students and his concern for them was extraordinary. He is sorely missed by the hundreds of friends he made during his few short years at M.I.T.

John C. Slater, Institute Professor Emeritus, died in July 1976. Professor Slater was one of the world's leading atomic and solid-state physicists; he was at the forefront of his field even as a young scientist. He came to M.I.T. as Head of the Department of Physics in 1930, the same year that the late Dr. Karl T. Compton became President, and played a prominent role in the transformation of M.I.T. into a major force in science. His early work in solid-state physics led to the development of the transistor. During World War II his work at the M.I.T. Radiation Laboratory led to a general theory of the operation of the magnetron oscillator and the transmission of microwaves. Following the war, Professor Slater was a prime mover in the establishment of M.I.T.'s Research Laboratory of Electronics and Laboratory for Nuclear Science, and nearly 20 years later his interests in the electrical, magnetic, and other properties of materials guided the plans for establishing M.I.T.'s interdepartmental Center for Materials Science and Engineering. Professor Slater was named M.I.T.'s first Institute Professor in 1951, setting the standard for this faculty position which recognizes individuals whose contributions have had broad effect throughout M.I.T.

Hans-Lukas Teuber, Head of the Department of Psychology, died suddenly in January 1977, at the age of 60. Professor Teuber had been Professor of Psychology at M.I.T. since 1961 and Head of the Department, which he founded, since 1964. A gifted scholar and teacher, Dr. Teuber set new standards of conceptual breadth and logical rigor in the study of the relationship between brain and behavior -- in perception, cognition, language, and memory. He was an inspiring and charismatic teacher, whose introductory psychology course was for many years the most popular undergraduate elective at M.I.T. A man who melded the instinct of a penetrating experimenter, the consummate style of a gifted teacher, and the sympathetic experience of a true humanist, his death was a most tragic and personal loss for many at M.I.T.

These men and women have been outstanding examples of the strength and variety of M.I.T.; they will be remembered and honored by generations of their students, friends, and associates.

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 1976-77.

Registration

In 1976-77 student enrollment was 8,597, an increase of 115 over the 8,482 enrolled in 1975-76. This total was comprised of 4,468 undergraduates and 4,129 graduate students. Graduate students who entered M.I.T. last year held degrees from 368 colleges and universities, 220 American and 148 foreign. The foreign student population was 1,491, representing 17 percent of the total population. The foreign students were citizens of 94 countries.

Degrees awarded by the Institute in 1976-77 included 1,018 bachelor's degrees, 971 master's degrees, 91 engineer's degrees, 379 doctoral degrees -- a total of 2,459.

The number of women at M.I.T., both graduate and undergraduate, has increased continually. In 1976-77, there were 1,361 women students at the Institute, compared with 1,255 in 1975-76. In September 1976, 173 first-year women entered M.I.T., representing 16 percent of the entering class. In 1976-77, a total of 329 degrees was awarded to women.

Student Financial Aid

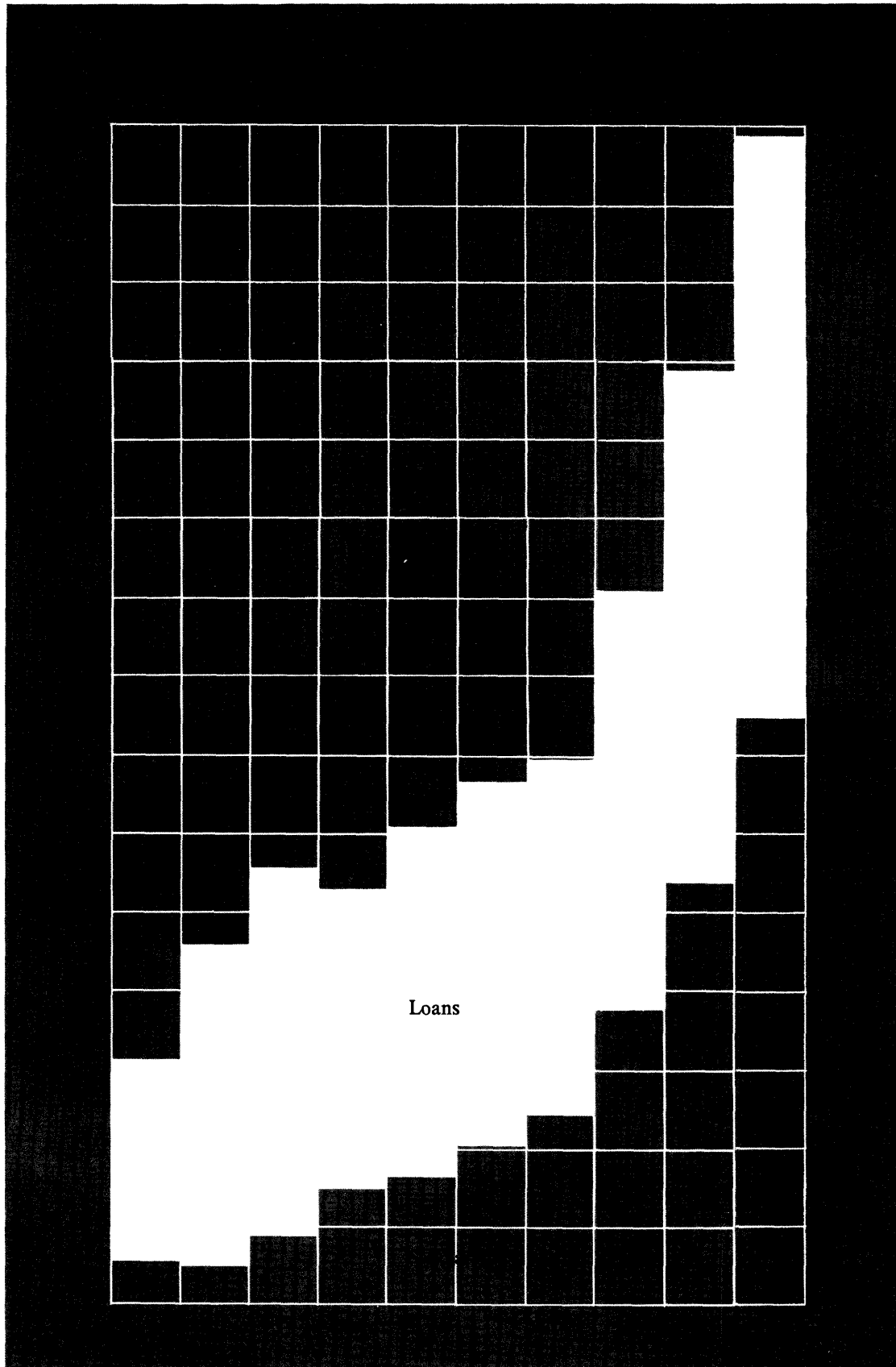
During 1976-77 the student financial aid program was again characterized by increases in total awards, in loans made, and in the amount of scholarship assistance. There was a significant increase in the number of individuals assisted.

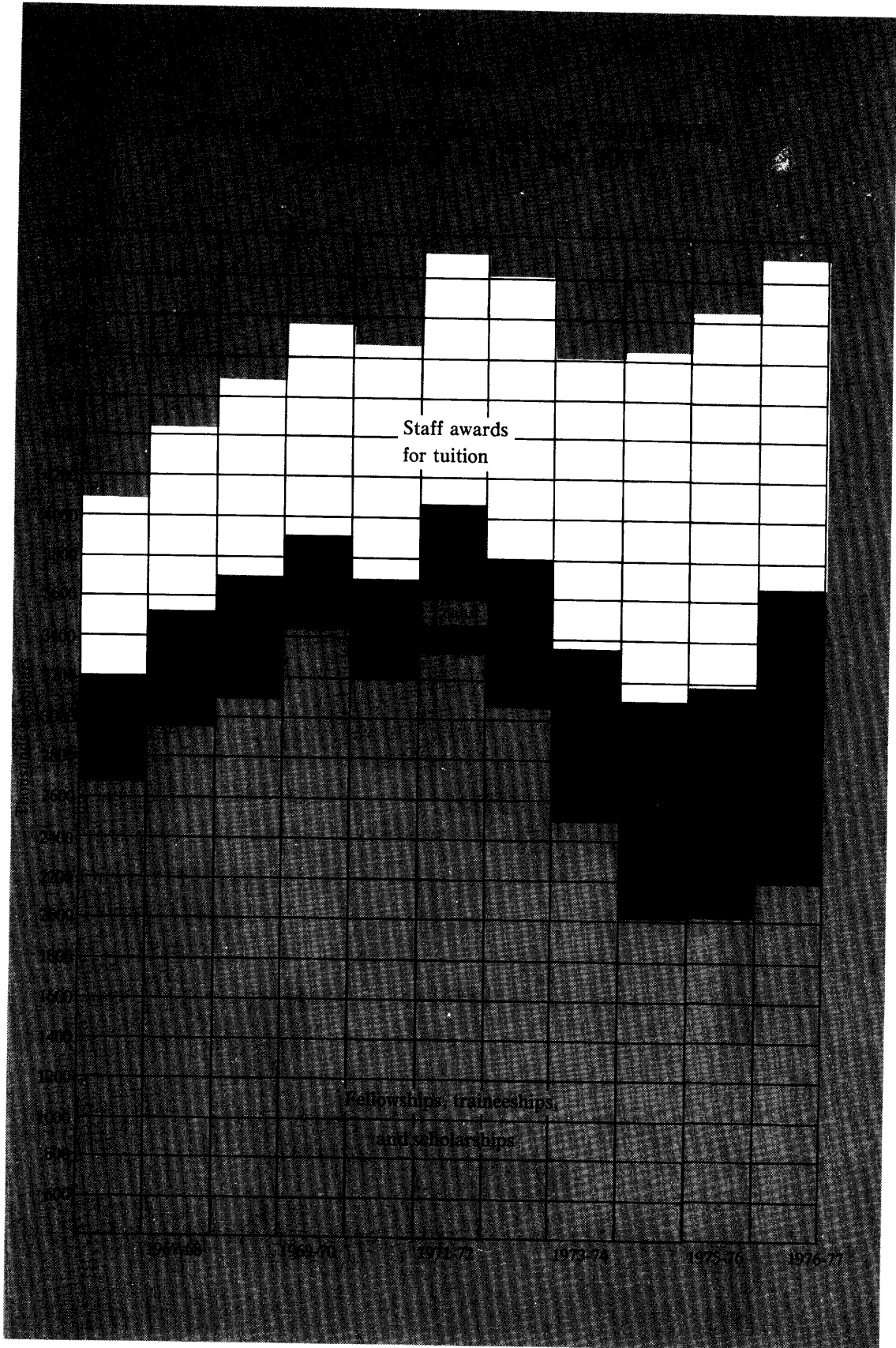
A total of 2,131 undergraduates who demonstrated the need for assistance (47 percent of the enrollment) received \$5,105,653 in scholarship aid and \$2,966,836 in loans. The total, \$8,072,489 represented a 14 percent increase in direct aid over last year.

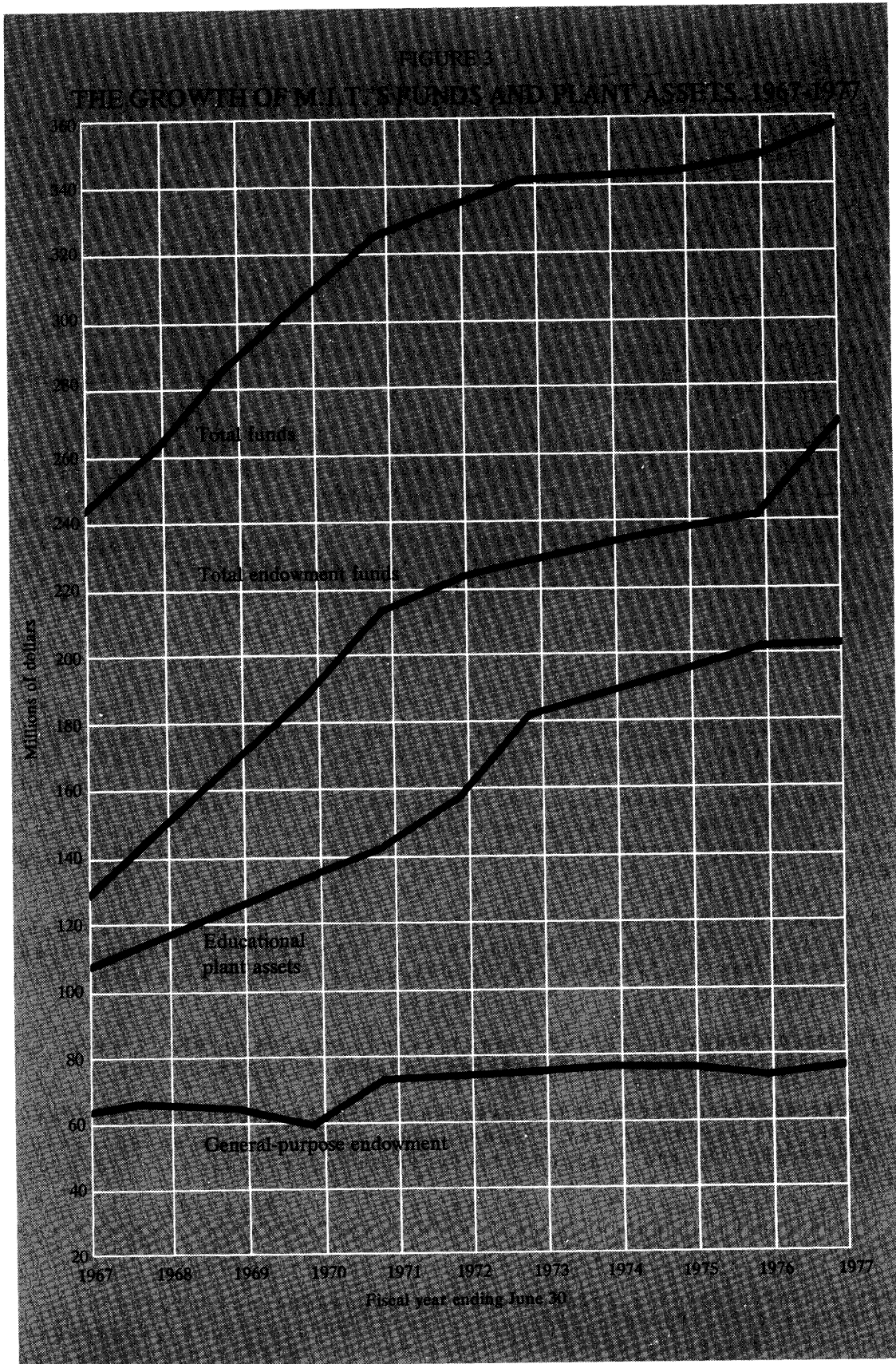
Scholarship assistance was provided by the scholarship endowment in the amount of \$2,137,709, by outside gifts for scholarships in the amount of \$751,801, and by direct grants to needy students totaling \$1,133,698 (an increase of 32 percent). Scholarship assistance from M.I.T.'s own operating funds was provided to the extent of \$949,773 (a 131 percent increase). The special program of scholarship aid to minority group students represented an additional \$132,672 from specially designated funds. An additional 395 students received direct grants from outside agencies, irrespective of need, in the amount of \$1,147,541. Outside scholarship support thus totaled \$3,033,040, another substantial increase over last year's total. A significant portion of the increase was again due to increased funding of the Federal government's grant-aid program. The undergraduate scholarship endowment was aided by the addition of new funds which represented an increase of \$1,509,557 and which raised the principal of the endowment to \$24,965,664.

Loans totaling \$2,966,836 were made to needy undergraduates. Of this amount, \$1,028,908 came from the Technology Loan Fund, \$1,928,928 from the National Defense Loan Fund, and the remainder from other M.I.T. loan funds. An additional \$765,800 (a 53 percent increase) was obtained by undergraduates from state-administered Guaranteed Loan Programs and other outside sources.

Graduate students obtained \$1,419,385 from the Technology Loan Fund. Of this total, \$659,295 was loaned under the Guaranteed Loan Program and qualified for Federal interest subsidies and guarantees. The total loaned by M.I.T. to both graduate and undergraduate students was \$4,402,214, an increase of \$486,443 over last year's total.







Career Planning and Placement

The relevance of M.I.T.'s style of teaching and research to the needs of the world is nowhere more apparent than in the eagerness with which private firms and government agencies seek the Institute's graduates. To be sure, graduates in some fields in recent years have found the employment market depressed, and this was so again last year, but in general the demand for M.I.T. talent in 1976-77 showed characteristic strength. More private firms used the interview facilities of the Career Planning and Placement Office than in any year since 1968-69, the last of the boom years of the 1960s. Recruiting by government agencies was down slightly from recent years, but recruiting activity overall matched the level of 1969-70. In some fields, notably in chemical, electrical, and mechanical engineering, and at the master's degree level in management, there were more recruiters on campus than available students. Students seized the opportunity presented to them and the Career Planning and Placement Office, not to mention other interview locations around the Institute, was the scene of more than 5,600 interviews. This figure, too, approaches the traffic of the 1960s.

Improved economic conditions were reflected in a continuing decline in the number of alumni registering with the Office. The number dropped to 454 from 522 in 1975-76 and 627 the year before. Characteristically, there was an increase in the number of job descriptions received from employers seeking experienced personnel. As usual, the strongest demand from employers was for recent graduates in fields enjoying current growth. A large part of the Office's work is in helping alumni with a number of years behind them who wonder whether their careers have taken them in the right direction, and who would like to explore the alternatives that may be open to them.

Finances

As reported by the Vice President for Financial Operations and the Treasurer, the total financial operations of the Institute, including sponsored research, increased from the level of 1975-76. Education and general expenses -- excluding the direct expenses of departmental and interdepartmental research, and the Lincoln Laboratory -- amounted to \$117,057,000 during 1976-77, compared to \$110,259,000 in 1975-76. Reflected in the finances of the Institute was the decrease in the use in operations of unrestricted funds to \$5,801,000, compared with \$6,493,000 in the preceding year.

The direct expenses of campus departmental and interdepartmental sponsored research increased from \$72,916,000 to \$77,804,000 and the direct expenses of the Lincoln Laboratory's sponsored research decreased from \$84,517,000 to \$80,503,000 because of a decline in subcontracts and outside purchases.

The construction program of the Institute continued to make progress in 1976-77 with the book value of educational plant facilities increasing from \$201,823,000 to \$203,340,000.

At the end of the fiscal year, the Institute's investments, excluding retirement funds, students' notes receivable, and amounts due from educational plant, had a book value of \$332,706,000 and a market value of \$401,096,000. This compares to book and market totals of \$319,878,000 and \$401,006,000 last year.

Gifts

Gifts, grants and bequests to M.I.T. from private donors increased from \$22,393,000 in fiscal year 1975-76 to \$26,899,000 in fiscal year 1976-77. The latter figure includes unrestricted direct gifts to the Alumni Fund of \$1,970,000 which constituted part of the total of \$4,851,000 reported by the Alumni Fund in 1976-77.

Physical Plant and Campus Environment

Completed during the year was the restoration of Bexley Hall, a major rehabilitation effort which included the renovation of all bathrooms and kitchens, replacement of basic electrical and mechanical systems, and the general upgrading of living space. With the assistance of the Safety Office, the sprinkler systems were expanded in East Campus dormitories, Eastgate Married Student Apartments, and Tang Residence Hall. Also completed was a 4,000 gross square foot addition to the Cancer Research facility in the Seeley G. Mudd Building.

Currently under construction are a 13,000 gross square foot interim animal care facility on Vassar Street between the Cyclotron (Building 44) and the Parsons Laboratory for Hydrodynamics (Building 48); renovations to Huntington Hall (10-250) and to the first floor of Building 10 for an Alumni Center, Exhibition Hall, and Electric Power Systems Engineering Laboratory (EPSEL); and in the Sloan Automotive Laboratory (Building 31), a major combustion research facility -- a significant addition to the Energy Laboratory's research program. Included in this latter facility is a horizontal combustor capable of burning fossil fuels at the rate of 10,000,000 BTU/hr. Construction is also under way on a new outdoor track, field, and game facility expected to be completed in the fall and to be known as the Henry G. Steinbrenner (Class of 1927) Stadium.

As part of a continuing effort to bring the arts to the campus, a Henry Moore sculpture and a Tony Smith sculpture were installed, the former within the area of Killian Court and the latter sited at the west end of the campus adjacent to the Westgate residential complex.

Personnel Changes

CORPORATION

CHANGES OF APPOINTMENT

Crawford H. Greenewalt
Life Member Emeritus

Breene M. Kerr
Life Member

George J. Leness
Life Member Emeritus

Norman B. Leventhal
Ex Officio Member
President of the Alumni Association

Frank R. Milliken
Life Member

Clint W. Murchison, Jr.
Life Member

David A. Shepard
Life Member Emeritus

Gregory Smith
Life Member

ELECTIONS

W. Gerald Austen
Member

Yaichi Ayukawa
Member

Vincent S. Castellano
Member

David R. Clare
Member

W. Van Alan Clark, Jr.
Member

Henry A. Hill
Member

Charles G. Koch
Member

Jerry McAfee
Member

Denman K. McNear
Member

F. Richard Meyer, III
Member

David S. Saxon
Member

TERMS EXPIRED

Rebecca A. Donnellan
Member

W. H. Krome George
Member

Paul V. Keyser
Member

I. M. Pei
Member

Paul P. Shepard
Member

RESIGNATIONS

David R. Wilson
Member

FACULTY

DEATHS

Jeffrey L. Pressman
Associate Professor of
Political Science

Dale Runge
Assistant Professor in
Sloan School of Management

Hans-Lukas Teuber
Professor and Head of
Department of Psychology

RETIREMENTS

Michael B. Bever
Professor in Materials Science
and Engineering

Bernard S. Gould
Professor in Biology

E. Neal Hartley
Professor in Humanities

Thomas M. Hill
Professor in Sloan School of
Management

Patrick M. Hurley
Professor in Earth and Planetary
Sciences

J. Francis Reintjes
Professor in Electrical
Engineering and
Computer Science

Personnel Changes

John C. Sheehan
Professor in Chemistry

Clark C. Stephenson
Professor in Chemistry

RESIGNATIONS

Professors:

Eduardo F. Catalano
Architecture

Edward A. Mason
Nuclear Engineering

Charles L. Miller
Civil Engineering

K. Barry Sharpless
Chemistry

Nathan Sivin
School of Humanities and
Social Science

Associate Professors:

Michael S. Baram
Civil Engineering

Carl M. Bender
Mathematics

Jochen H. Heisenberg
Physics

Hubert E. Jones
Urban Studies and Planning

Maria C. Linder
Nutrition and Food Science

Loy D. Lytle
Nutrition and Food Science

Roy E. Marsten
Sloan School of Management

P. Narayan Nayak
Mechanical Engineering

Assistant Professors:

Floyd B. Barbour
Humanities

John R. Bennett
Earth and Planetary Sciences

Murray J. K. Biggs
Humanities

James D. Felske
Mechanical Engineering

James L. Gole
Chemistry

Frederick L. A. Grauer
Sloan School of Management

Rufus E. Hallmark
Humanities

D. Graham Holmes
Mechanical Engineering

Alexander Keyssar
Humanities

Peter B. Laytin
Architecture

Roberto L. Lenton
Civil Engineering

Charles J. Libby
Urban Studies and Planning

Izchak Miller
Linguistics and Philosophy

Miles Morgan
Linguistics and Philosophy

Owen H. Oakley
Ocean Engineering

Donald A. Preziosi
Architecture

Michael R. E. Proctor
Mathematics

David D. Redell
Electrical Engineering and
Computer Science

Jane Rosenkrans
Athletics

Adrian Segall
Electrical Engineering and
Computer Science

William A. Shaffer
Sloan School of Management

Melissa Shook
Architecture

John H. Terry
Architecture

Jefferson W. Tester
Chemical Engineering

Michael J. Underhill
Architecture

Hal R. Varian
Economics

Paul S. Wang
Mathematics

PROMOTIONS

To Professor:

Ulrich J. Becker
Physics

Eric R. Cosman
Physics

Stanley Fischer
Economics

Thomas J. Greytak
Physics

Roman W. Jackiw
Physics

President and Chancellor

Norman Jones
Ocean Engineering

Jerome H. Milgram
Ocean Engineering

Joel Moses
Electrical Engineering and
Computer Science

Harvey Sapolsky
Political Science

John G. Sclater
Earth and Planetary Sciences

Robert J. Silbey
Chemistry

Anthony J. Sinskey
Nutrition and Food Science

Joseph M. Sussman
Civil Engineering

Glen L. Urban
Sloan School of Management

David N. Wormley
Mechanical Engineering

Mark Wrighton
Chemistry

Vernon R. Young
Nutrition and Food Science

To Associate Professor:

Mohsen M. Baligh
Civil Engineering

Moshe E. Ben-Akiva
Civil Engineering

Ned J. Block
Linguistics and Philosophy

Kenneth Brecher
Physics

Susan Carey
Psychology

Whitney Chadwick
Architecture

Elzbieta E. Chodakowska
Humanities

Lloyd A. Clomburg, Jr.
Chemical Engineering

Robert C. Cohen
Chemical Engineering

Patricia Cumming
Humanities

John D. Fernstrom
Nutrition and Food Science

Ira P. Goldstein
Electrical Engineering and
Computer Science

Paul D. Gottlieb
Biology

Alan J. Grodzinsky
Electrical Engineering and
Computer Science

Michael Hammer
Electrical Engineering and
Computer Science

Dolores Hayden
Architecture

Nancy H. Hopkins
Biology

Jean E. Jackson
Humanities

Marc A. Kastner
Physics

James L. Kirtley, Jr.
Electrical Engineering and
Computer Science

Gary L. Lilien
Sloan School of Management

Ernest J. Moniz
Physics

Charles M. Oman
Aeronautics and Astronautics

Ronald L. Rivest
Electrical Engineering and
Computer Science

Nils R. Sandell, Jr.
Electrical Engineering and
Computer Science

Robert Slattery
Architecture

Sean C. Solomon
Earth and Planetary Sciences

Gerald J. Sussman
Electrical Engineering and
Computer Science

Nawal K. Taneja
Aeronautics and Astronautics

William G. Thilly
Nutrition and Food Science

Bonnie M. Tyler
Biology

Hal R. Varian
Economics

William C. Wheaton
Economics

Thomas R. Willemain
Urban Studies and Planning

To Assistant Professor:

Leonard M. Adleman
Mathematics

Andrea A. di Sessa
Division for Study and Research
in Education

Alexander Keyssar
Humanities

Monroe H. Little
Humanities

Personnel Changes

Ronald L. MacNeil
Architecture

Martin B. Zimmerman
Sloan School of Management

CHANGES OF APPOINTMENT

Harold Abelson
Assistant Professor in Division for
Study and Research in Education
and Electrical Engineering and
Computer Science

Alan A. Altshuler
Professor and Head of
Political Science

Benjamin C. Ball, Jr.
Adjunct Professor in Sloan School
of Management and School of
Engineering

Myra Brenner
Research Associate in Humanities

Gene M. Brown
Professor of Biochemistry and
Head of Department of Biology

Clark K. Colton
Professor and Deputy Department
Head of Chemical Engineering

Mildred S. Dresselhaus
Abby Rockefeller Mauzé Professor
of Electrical Engineering and
Computer Science and Director of
Center for Materials Science and
Engineering

Richard S. Eckaus
Ford Professor of Economics

Ebrahim Esmailzadeh
Visiting Assistant Professor
of Mechanical Engineering

Hilbert Fefferman
Visiting Professor of Urban
Studies and Planning

A. Rae Goodell
Assistant Professor of Humanities

John V. Harrington
Adjunct Professor of Electrical
Engineering and Computer Science

Richard M. Held
Professor and Head of Psychology

Thomas F. Jones
Vice President for Research and
Professor of Engineering

Alfred A.H. Keil
Ford Professor of Engineering in
School of Engineering

James L. Kinsey
Professor and Acting Head of
Department of Chemistry

Roberto L. Lenton
Visiting Assistant Professor of
Civil Engineering

Steven R. Lerman
Gilbert W. Winslow Assistant
Professor of Civil Engineering

Irving M. London
Grover M. Hermann Professor of
Health Sciences and Technology,
Professor of Biology and Director
of Harvard-M.I.T. Division of
Health Sciences and Technology

Edward N. Lorenz
Professor and Head of
Department of Meteorology

Gilbert W. Low
Assistant Professor in Sloan
School of Management

David C. Major
Visiting Associate Professor in
Department of Civil Engineering

Michael P. Manning
Du Pont Assistant Professor of
Chemical Engineering

Thomas B. McCord
Senior Research Scientist in
Earth and Planetary Sciences

Ole S. Madsen
Henry L. Doherty Associate
Professor of Civil Engineering

David Marr
Associate Professor of Psychology

Michael A. Moskowitz
Visiting Assistant Professor
of Nutrition and Food Science

Robert B. Newman
Adjunct Professor of Architecture

Ronald R. Parker
Professor of Electrical Engineering
and Computer Science

David M. Perlmutter
Research Associate of Linguistics
and Philosophy

Edward Pincus
Adjunct Professor of Architecture

Miklos Porkolab
Professor of Physics

Mary C. Potter
Associate Professor of Psychology

Frederick A. Putnam
Du Pont Assistant Professor of
Chemical Engineering

Dale Runge
Assistant Professor in Sloan
School of Management

Kenneth N. Stevens
Clarence Joseph LeBel Professor
of Electrical Engineering and
Computer Science

Gerald J. Sussman
Esther and Harold E. Edgerton
Associate Professor of
Electrical Engineering and
Computer Science

Joseph M. Sussman
Professor of Civil Engineering
and Associate Dean for
Educational Programs of
the School of Engineering

Samuel C. C. Ting
Holder of Thomas Dudley Cabot
Institute Chair in Department
of Physics

Robert J. Van Houten
Assistant Professor of Ocean
Engineering

Judith G. Wechsler
Research Associate in Center for
Advanced Visual Studies

Myron Weiner
Ford Professor of Political Science

Stanley A. West
Research Associate in Civil
Engineering

George M. Whitesides
Arthur C. Cope Professor of
Chemistry

Carl I. Wunsch
Professor and Acting Head of
Department of Earth and
Planetary Sciences

Lewis D. Wurgaft
Lecturer in Humanities

NEW FACULTY APPOINTMENTS

Professor:

B. Clark Burchfiel
Earth and Planetary Sciences

Jeffrey Goldstone
Physics

Samuel Keyser
Professor and Head of Department
of Linguistics and Philosophy

Robert C. Seamans, Jr.
Henry R. Luce Professor of
Environment and Public Policy,
Institute Wide

James Wei
Warren K. Lewis Professor
and Head of Department of
Chemical Engineering

Associate Professor:

Henri Brunengraber
Nutrition and Food Science

William H. DuMouchel
Mathematics

Margery Resnick
Humanities

Richard L. Schmalensee
Sloan School of Management

Gunther Werner
Mechanical Engineering

Assistant Professor:

David B. Ashley
Civil Engineering

Lawrence S. Bacow
Urban Studies and Planning

Carliss Y. Baldwin
Sloan School of Management

Michael J. Bevan
Biology

Gabriel R. Bitran
Sloan School of Management

Edward A. Boyle
Earth and Planetary Sciences

Donald Corner
Architecture

Michael E. Crawford
Mechanical Engineering

Rick L. Danheiser
Chemistry

Randall Davis
Electrical Engineering and
Computer Science

Charles C. Eriksen
Earth and Planetary Sciences

Henry S. Farber
Economics

Terry L. Friesz
Civil Engineering

Alan K. Graham
Sloan School of Management

Stephen C. Graves
Sloan School of Management

Steven K. Gregory
Architecture

Irene G. Greif
Electrical Engineering and
Computer Science

Edward M. Greitzer
Aeronautics and Astronautics

Jean A. Heiney
Athletics

Jennifer Humphrey
Humanities

Harry C. Katz
Economics

Eric S. Maskin
Economics

Arno R. Minkinen
Architecture

Francis Noblesse
Ocean Engineering

James G. Paradis
Humanities

Thomas Postlewait
Humanities

Robert O. Ritchie
Mechanical Engineering

Kevin W.S. Roberts
Economics

Personnel Changes

Charles F. Sabel
School of Humanities and
Social Science

Michael M. Salour
Electrical Engineering and
Computer Science

Robert N. Scanlan
Humanities

Selim M. Senkan
Chemical Engineering

Marilyn J. Simon
Economics

Noel W. Solomons
Nutrition and Food Science

Deborah A. Stone
Political Science

Stephen J. Tapscott
Humanities

William C. Unkel
Mechanical Engineering

Costas G. Vayenas
Chemical Engineering

Margaret H. Weiler
Physics

Jenny Young
Architecture

Michael D. Zisman
Sloan School of Management

Adjunct Professor:

Gunter Stein
Electrical Engineering and
Computer Science

James S. Hekimian
Sloan School of Management

VISITING FACULTY

Visiting Professor:

Bijan Aalami
School of Engineering

Samuel W. Allen
Humanities

Edward E. Azar
Political Science

Albert W. Bally
Earth and Planetary Sciences

Keith Boyer
Physics

Felix Browder
Mathematics

Jerome S. Bruner
Division for Study and Research
in Education

John F. Burke
Nutrition and Food Science and
Director of the Clinical
Research Center

Tien S. Chang
Physics

C. Roland Christensen
Sloan School of Management

Henry S. Commager
Humanities

Avinash K. Dixit
Economics

Yu-Chi Ho
Electrical Engineering and
Computer Science

Erich P. Ippen
Electrical Engineering and
Computer Science

Harry G. Judge
Division for Study and Research
in Education

Ita Kaiserman-Abramof
Psychology

Joseph L. Katz
Chemical Engineering

Daniel P. Loucks
Civil Engineering

James L. Massey
Electrical Engineering and
Computer Science

Dan P. McKenzie
Earth and Planetary Sciences

George A. Miller
Linguistics and Philosophy
and Psychology

Lennart Philipson
Biology

William Poole
Economics

Peter Prangnell
Architecture

Glen A. Rebka
Physics

Vincent Roggeveen
Civil Engineering

Bertrand Schwartz
Division for Study and Research
in Education

Hermine J. Sinclair-de Zwart
Division for Study and Research
in Education

Carl Spight
Physics

Thirukodikaval N. Srinivasan
Economics

Kiyohide Terai
Ocean Engineering

Ernest O. Tuck
Ocean Engineering

Sam B. Warner
Architecture

Joseph Weneser
Physics

Lynn T. White
School of Humanities and
Social Science

Heinrich Zollinger
Mechanical Engineering

Visiting Associate Professor:

Mary Amdur
Nutrition and Food Science

Avram Bar-Cohen
Mechanical Engineering

Philip C. Clapp
Materials Science and Engineering

Igor Dolgachev
Mathematics

Jean-Francois Gabriel
Architecture

Christoph Haehling von Lanzenauer
Sloan School of Management

James L. Hodges
Chemical Engineering

Moshe Israeli
Mathematics

Harold J. Metcalf
Physics

Louis A. Raphael
Mathematics

William H. Reed
Nuclear Engineering

William E. Taylor
Economics

Barbara A. Underwood
Nutrition and Food Science

Michele F. Vergne
Mathematics

Visiting Assistant Professor:

Isabelle de Courtivron
Humanities

Robert S. Langer, Jr.
Nutrition and Food Science

Johanna Lessinger
Humanities

Friedrich Prinz
Mechanical Engineering

Jagdish Shukla
Meteorology

AWARDS

Hans-Lukas Teuber
Killian Award Lecturer for the
Academic Year 1976-77

ADMINISTRATION

DEATHS

Peter G. Bronchuk
Assistant Accounting Officer
Comptroller's Accounting
Office

Melvin Cabral
Administrative Officer
Department of Civil
Engineering

Matthew Bryce Leggett
Associate Director
Admissions Office

Joseph Lynch
Assistant Director
Housing Office

Allan J. Urquhart
Benefits Officer
Office of Personnel Relations

RETIREMENTS

Leo D. Caplice
Administrative Officer
Medical Department

John A. Carley
Personnel Officer for Special
Services
Office of Personnel Relations

G. Peter Grant
Director for Clubs
Alumni Association

Thaddeus W. Kowlicik
Personnel Administrator
Comptroller's Accounting Office

Mary J. Manning
Administrative Assistant
Educational Council

Personnel Changes

Robert J. Radocchia
Manager
Food Services

Thomas Saxon, Jr.
Supervisor, Internal Review
and Disbursements
Lincoln Fiscal Office

RESIGNATIONS

Claudia W. Adair
Assistant to the Wage
and Salary Administrator
Office of Personnel Relations

Grace Ackerman-Lewis
Systems Programmer
Information Processing
Services

Gene F. Armstrong
Senior Systems Analyst
Information Processing
Services

Henry B. Barg
Industrial Liaison Officer
Industrial Liaison Office

Ann M. Beha
Administrative Assistant
Department of Architecture

Frederick C. Bentley II
Assistant Director
Office of Sponsored Programs

Jean Bow
Senior Programming Analyst
Information Processing Services

Kenneth S. Brock
Director of Resource Operations
Resource Development

Paul H. Burr
Institute Secretary for
Foundations
Vice President, Resource
Development

Antoinette Calavas
Supervisor, Information Services
Information Processing Services

Virginia A. Dean
Assistant Manager, Personnel
Information Services
Office of Personnel Services

David W. Dove
Assistant Director
M.I.T. Associates Program

John O. Flender
Secretary, M.I.T. Development
Foundation
Office of the President and the
Chancellor

Ann B. Gordon
Assistant Dean for Academic
Administration
School of Architecture and
Planning

Suzanne Hansen
Administrative Dietician
Dining Service

William J. Hecht
Director
Educational Council

David M. Jordan
Systems Programmer
Information Processing Services

David Judelson
Assistant Director
Laboratory of Architecture and
Planning

Dexter J. Kamilewicz
Assistant Director
Housing Office

Rachel L. Kohl
Technical Supervisor
Information Processing Services

Robert W. Krieg
Project Manager
Information Processing Services

Frederick G. Lehmann
Director, Alumni Fund
Alumni Association

William R. MacDonald
Systems Programmer
Information Processing Services

Patricia A. Mahon
Production Manager
M.I.T. Press

Patricia Maroni
Staff Writer/Editor
Resource Planning

Kevin R. McDonagh
Administrative Officer
Physical Plant

James W. McGurl
Administrative Officer
Department of Nutrition and
Food Science

Lawrence McKinnon
Administrative Assistant
Department of Nutrition and
Food Science

Elaine B. Medverd
Administrative Assistant to the
Director
Division for Study and Research
in Education

Dennis L. Meredith
Staff Writer/Editor
Alumni Association

Diane C. Michalik
Associate Director, Undergraduate
Research Opportunities Program
Office of the President and
the Chancellor

Pamela L. Northridge
Programming Analyst
Information Processing Services

Martha M. Pennell
Senior Applications Analyst
Office of Facilities Management
Systems

Emily Rosenthal
Manager of Text Sales
M.I.T. Press

Martin M. Santa
Patent Attorney
Patent Office

Penelope H. Schafer
Economic Advisor to the President,
Harvard and M.I.T.
Joint Center for Urban Studies

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

Robert Shillington
Applications Programmer
Information Processing Services

Ena C. Squires
Assistant to the Director
Alumni Association

Richard M. Stetson
Senior Systems Programmer
Information Processing Services

Gerald L. Swanson
Programming Analyst
Information Processing Services

John Peter Tower
Senior Staff Accountant
Student Accounts Office

Bruce H. Wheeler
Applications Programmer
Information Processing Services

Gail P. Wilson
Assistant to the Director
Admissions Office

Helenmarie G. Zachritz
Family Day Care Developer
Child Care Office

APPOINTMENTS AND CHANGES

Patricia R. Anderegg
Administrative Assistant
Department of Nutrition and
Food Science

Edwin M. Arippol
Industrial Liaison Officer
Industrial Liaison Office

Jurate J. Barnes
Campaign Room Manager
Resource Planning

Paul F. Barrett
Associate Director
Physical Plant

Jonathan H. Bartels
Assistant Director
Office of Sponsored Programs

Sharon Basco-Koch
Publicity Manager
M.I.T. Press

Martha L. Bertrand
Assistant Director in Donor
Relations
Resource Planning

Carmen Rivas Besterman
Special Assistant
Office of the President and
the Chancellor

Himangshu Bhattacharya
Senior Applications Analyst
Information Processing Services

William J. Billings
Administrative Officer
Department of Physics

Cynthia C. Bloomquist
Director
M.I.T. Associates Program

Jean C. Bonney
Director of Computer Services
and Academic Research
Information Processing Services

Carol M. Bostick
Senior Staff Accountant
Treasurer's Office

Maria Ann Bozzuto
Programming Analyst
Information Processing Services

Mary E. Branum
Technical Writer
Information Processing Services

Jane A. Browning
Program Coordinator
Sloan School of Management

Allan S. Bufferd
Assistant Treasurer
Treasurer's Office

Rae K. Burns
Programming Analyst
Information Processing Services

Francis A. Canali
Systems Planner
Information Processing Services

Deborah J. Colaw
Programming Analyst
Information Processing Services

Isaac M. Colbert
Senior Consultant Trainer
Office of Personnel Development

Joseph S. Collins
Associate Director, Alumni Fund
Alumni Association

Harvey J. Connor
Staff Accountant
Comptroller's Accounting Office

Robert J. Conrad, Jr.
Senior Systems Programmer
Information Processing Services

Glenn T. Curtis
Manager, Institute Printing and
Copying
Graphic Arts Services

Personnel Changes

D. Hugh Darden
Director, Planned Giving and
Advisor, Legal Affairs
Vice President for Resource
Development

Maureen DeCourcey
Manager, Student Loan Office
Student Accounts Office

Alfred R. Doig, Jr.
Senior Industrial Liaison Officer
Industrial Liaison Office

Mary Ann Donofrio
Senior Staff Accountant
Comptroller's Accounting Office

Martha S. Draper
Associate Director, Alumni Fund
Alumni Association

Joseph A. Edwards
Director
Educational Council

Harris D. Eigabroadt
Manager, Video Operations and
Maintenance
Center for Advanced Engineering
Study

Mary Z. Enterline
Writer/Editor
Office of the Provost

Brenda L. Ferriero
Technical Supervisor
Information Processing Services

Jill A. Gilpatric
Staff Writer and Editor
Department of Athletics

Joyce J. Graham
Programming Analyst
Information Processing Services

James E. Grayson
Assistant Director
Office of Sponsored Programs

Patricia K. Greer
Assistant Director
Office of Sponsored Programs

David J. Griffiths
Programming Analyst
Information Processing Services

Robert E. Gorman, Jr.
District Officer
Volunteer Leadership Campaign

David J. Harrigan
Research Coordinator
Office of Sponsored Programs

Jeffrey C. Harrington
Applications Programmer
Information Processing Services

Donna P. Hawrot
Systems Programmer
Information Processing Services

Holliday C. Heine
Assistant Dean
Dean for Student Affairs

Thomas R. Henneberry
Assistant Director, Planned Giving
Vice President for Resource
Development

Donna M. T. Herlehy
Assistant Director
Office of Sponsored Programs

Sally M. R. Hughes
Administrative Dietician
Food Services

Maureen K. Huguenin
Assistant to the Director
Office of Sponsored Programs

Patricia Joffe
Assistant to Undergraduate Public
Policy Program Director
Department of Political Science

Eric C. Johnson
Assistant Director
Industrial Liaison Office

Bruce L. Katz
Manager, Text Sales
M. I. T. Press

F. Judith Klayman
Health Planner
Medical Department

Florence C. Ladd
Assistant Dean for Academic
Administration
School of Architecture and
Planning

Norman D. Lang
Manager, Video Instruction
Center for Advanced Engineering
Study

Caroline A. Lange
Supervisor, Public Services
Information Processing Services

Steven A. Lanney
Assistant Accounting Officer
Comptroller's Accounting Office

Frederick D. Leach
Area Coordinator
Information Processing Services

Nelson C. Lees
Executive Director of Resource
Development and Director of
Resource Planning
Vice President for Resource
Development

Walter Lehmann
Assistant Director
M. I. T. Associates Program

John P. Leonard
Associate Comptroller
Comptroller's Accounting Office

Kenneth F. LeVie
Budget Officer
Fiscal Planning and Budget Office

Nancy K. Lombardi
Staff Assistant to the Vice President
Office of the President and
the Chancellor

Judith A. Lugas
Senior Applications Analyst
Office of Facilities Management
Systems

President and Chancellor

John L. Mack
Associate Director
Admissions Office

Howard A. Markowitz
Liaison Officer
Vice President for Research

Robert F. Matson
Systems Analyst
Information Processing Services

James H. McCarthy
Administrative Officer
Division for Study and Research
in Education

Ann S. McCormick
Student Loan Collection Officer
Student Accounts Office

James McTigue
Senior Staff Accountant
Student Accounts Office

Frank O. Melanson
Documentation Manager
Information Processing Services

Anne K. Mengler
Assistant to the Director,
Development Office
Resource Planning

Irene C. Merwin
Assistant Coordinator for Health
Information and Education
Medical Department

Stanley Miller
Senior Accounting Officer
for Benefits
Comptroller's Accounting Office

Walter E. Morrow, Jr.
Director
Lincoln Laboratory

Carsten C. Mortensen
Applications Programmer
Information Processing Services

Christopher L. Mullendore
Systems Programmer
Information Processing Services

Rita F.P. Nethersole
Assistant Student Financial
Aid Officer
Student Financial Aid Office

Sara Jane Neustadt
Managing Editor, Technology Review
Alumni Association

Keiko F. Oh
Administrative Officer
Harvard-M.I.T. Program in
Health Sciences and Technology

Ellen O. O'Hara
Administrative Assistant
Office of Personnel Development

Albert K. Paone
Assistant Director
Graphic Arts Services

Kimball E. Pierce
Systems Programmer
Information Processing Services

Felicia Pleuthner
Senior Systems Analyst
Information Processing Services

Gerald M. Ponce
Assistant Director, Administrative
Computing Services
Information Processing Services

James F. Purtell
Technical Supervisor
Information Processing Services

Laxmi J. Rao
Data Base Manager
Office of Facilities Management
Systems

Robert R. Ragusa, Sr.
Personnel Administrator
Comptroller's Accounting Office

Wayne Richards
Manager, Computer Facility
Information Processing Services

Margaret Richardson
Supervisor of the Undergraduate
Physics Office
Department of Physics

William O. Risinger, Jr.
Technical Supervisor
Information Processing Services

Arturo A. Rosales
Assistant Director
Industrial Liaison Office

Marco Sarmiento
Applications Programmer
Information Processing Services

Harry A. Schade
Staff Accountant -- Special
Cost Studies
Comptroller's Accounting Office

Richard D. Scott
Programming Analyst
Information Processing Services

Warren A. Seamans
Director, Historical Collections
Libraries

Robert E. Shaw
Assistant Director
Housing Office

Sophia Sieczkowski
Administrative Assistant
Department of Architecture

Victoria V. Sirianni
Interior Designer/Planner
Physical Plant

H. Dany Siler
Assistant to the Director
Admissions Office

Lydia S. Snover
Administrative Officer
Department of Nutrition and
Food Science

Judith W. Spall
Senior Systems Programmer
Information Processing Services
Operations

Victoria Spencer
Administrative Assistant,
New York Alumni Center
Alumni Association

Personnel Changes

Sylvia Steiner
Design Manager
M. I. T. Press

Brooke Stevens
Promotion Manager
M. I. T. Press

Ronald S. Stone
Regional Director
Alumni Association

Stanley W. Sundstrom
Applications Programmer
Information Processing Services
Operations

Marjory A. Supovitz
Project Director
Committee on the Visual Arts

Mark W. Tanguard
Editor/Writer
Information Processing Services
Operations

Paul S. Tasner
Editor/Writer
M. I. T. Press

Walt C. Taylor
Curator, Historical Collections
Libraries

Diane F. Thilly
Legal Assistant to the General
Counsel
Patent Office

William M. Toscano
Staff Accountant
Comptroller's Accounting Office

Philip A. Trussell
Investment Real Estate Officer
Treasurer's Office

Seichi Tsutsumi
Industrial Liaison Officer
Industrial Liaison Office

John B. Turner
Associate Dean, Administration
Dean of the Graduate School

Therese M. Viohl
Assistant to the Wage and Salary
Administrator
Office of Personnel Relations

Herkus W. Von Letkemann II
Senior Systems Analyst
Information Processing Services Operations

Philippa J. Warner
Family Day Care Program Developer
Child Care Office

Richard D. Woelflein
Production Manager
M. I. T. Press

Marina Xydeas
Applications Programmer
Resource Planning

Barbara V. Zeilenga
Manager, Donor Relations and
Assistant Director
Resource Planning

Gail P. Zimmermann
Production Manager, Design
Services
Campus Information Services



Dean for Student Affairs

Perhaps the most important accomplishment of the past academic year has been our success in maintaining the quality of extracurricular life despite the simultaneous increase in the number of students and decrease in the number of Dean's Office staff. This success is a credit to the cooperative spirit of our students, as well as to the yeoman performance of a smaller but dedicated staff.

Dean Peter Büttner, the Executive Officer of the Freshman Advisory Council (F. A. C.) and one of our most loyal and accomplished staff members, is attending the Sloan School of Management this year. All of us join in wishing him every success. The report of the Freshman Advisory Council Steering Committee, under the chairmanship of Professor Hartley Rogers, is now available and recommends the establishment of the position of Director of the Office of Freshman Advising, the abolition of the position of Faculty Chairman of the Freshman Advisory Council, and the substitution of a Committee on Freshman Advising appointed by the President. We are now in the process of searching for the most appropriate individual to serve as Director. In the interim, Dean Bonny S. Kellermann has done a first-rate job in maintaining the F. A. C. program and planning for the coming year.

The departure of Anne Thompson, Assistant Dean with special responsibility for women's programs, left us with a major vacancy at the beginning of the academic year. A Search Committee, chaired by Dean James Bishop, reviewed more than 120 applicants. The final choice was Holliday Heine, an M. I. T. graduate with a doctorate in Biology, and with all the requisite gifts of personality and understanding to become both a leader in the area of women's affairs as well as an excellent counselor. Her performance has lived up to her promise.

In the housing system, we suffered a real loss when Professor and Mrs. Murray Eden left Senior House to take a position in Washington. After a long and careful search, we were fortunate in recruiting Professor and Mrs. Bora Mikic who have proved to be splendid successors. Sadly, Professor and Mrs. James Bruce have decided to retire from Burton-Connor because of the press of other responsibilities. The Institute owes them a debt of gratitude for a job well done. We are in the process of searching for their replacement.

The many and difficult problems of accommodating the larger number of first-year students ever were solved with éclat by Dean Kenneth Browning and his associates. The new fraternity, Alpha Delta Phi, and the new Women's Independent Living Group had successful first years. New House has continued to do well, thanks to Professor James Williams and Karen Goodall, the faculty in residence.

Women's athletics at M. I. T. achieved an excellent year, both from the point of view of expanded activity and student satisfaction, under the leadership of the new Director of Women's Athletics, Jane Betts.

Dean James Bishop was selected to attend the six-week Institute for Educational Management Program at the Harvard Business School this summer.

Several of our staff members have cheerfully assumed extra responsibilities this year and deserve special recognition. Dean Robert Holden, in addition to his usual duties, assumed

responsibility for the Student Center and Kresge Auditorium following Dean Jon Hartshorne's departure last year. These facilities continue to function efficiently under his direction in spite of the ever-present problem of space limitation. Dean Susan Houpt is doing an excellent job running Talbot House, another of Dean Hartshorne's former responsibilities. Dean Alice Seelinger has added housing to her varied and full list of tasks, and has been of inestimable value in meeting the challenge of housing a larger freshman class.

Within the Dean's Office, one of our most productive efforts was a Self-Study Committee, chaired by Dean Browning, which produced a series of thoughtful recommendations for improving both our internal and external operations. With respect to the latter, we have been concerned about the limited understanding of the functions of the Office among faculty as well as students. We are currently discussing various proposals designed to increase input from students, faculty, and staff into the key decisions that must be made by our office, and to make all members of this community more aware of the services we perform.

Finally, the Dean for Student Affairs notes the daily gratification she derives from her relationships with the always exciting and stimulating M.I.T. student population, both graduate and undergraduate. She continues to serve as advisor to first-year and premedical students, to give an undergraduate seminar, to have open house in her office during R/O week, and to have periodic meetings at her home to discuss careers in medicine and other topics with students. She notes with pride and pleasure the number of students who brought their parents to meet her at graduation because they wanted to share with her their moment of success. It is always heartwarming when dealing with our students that meetings which begin with complaints and dissatisfactions most often end with the pleasure of good and lasting friendships. And it is these friendships which continue to make the hard work and the inevitable frustrations of the Dean's job worthwhile.

CAROLA EISENBERG

Freshman Advisory Council (F.A.C.)

Two hundred sixty-seven faculty, graduate students, and staff volunteered to serve as advisors to a class consisting of 1,056 first-year students. The number of volunteers by category was: faculty, 117; instructors and lecturers, 30; graduate students, 48; staff, 72. These numbers are roughly comparable to the prior year, except for a 30 percent reduction in the staff category presumably resulting from reduced recruitment. More than 240 advisors had upperclass men and women working with them as associate advisors.

There were no significant changes in the academic options available to first-year students. Anecdotal evidence suggested that, at least in the fall, they continued to follow observed trends of recent years and seemed to be working even harder than their predecessors. End-of-term statistics on academic performance tended to bear this out, with the smallest number of letters being sent in recent years (3 percent received Committee on Academic Performance Warnings). The number of first-year C.A.P. actions increased in the spring, but were still fewer than last year. C.A.P. Warning letters were sent to 47 students (4.5 percent of the class) and 17 students (1.6 percent of the class) were asked to withdraw.

During the fall and winter the F.A.C. staff continued the practice of meeting in small groups with advisors and associate advisors. Over 68 percent of the advisors attended these sessions, exchanging ideas among themselves and providing feedback to the staff. Staff members

Freshman Advisory Council

regularly participated in meetings of the F.A.C. Steering Committee, the Advisory Committee to the Office of Minority Education, the C.A.P., the Committee on Undergraduate Admissions and Financial Aid, R.O.T.C., and the Community Service Fund, and also the WTBS Foundation. Several open houses provided the opportunity to acquaint first-year students with the small but growing collection of materials in the new Resource Room. Counseling of individual students continued at the level of previous years and group discussions of topical interest were held throughout the year.

The use of freshman evaluation forms was somewhat lower than in previous years. Taking a sample of 50 students, we examined their utilization of evaluation forms and the results are as follows:

	<u>Fall Mid-Term</u>	<u>Fall End-of-Term</u>	<u>Spring Mid-Term</u>	<u>Spring End-of-Term</u>
Student initiated	177/274 (65%)	129/267 (48%)	144/262 (55%)	79/241 (33%)
Instructor initiated	<u>13/274 (5%)</u>	<u>14/267 (5%)</u>	<u>8/262 (3%)</u>	<u>15/241 (6%)</u>
Total # of Forms Filed	190/274 (70%)	143/267 (53%)	152/262 (58%)	94/241 (39%)

In addition to serving as associate advisors, undergraduates continued to contribute significantly to Freshman Advisory Council activities. Alan Mink, Class of 1979, coordinated the group of students who ran Residence/Orientation week. John Shelton, Class of 1979, has been organizing and planning efforts for welcoming the new class this September. Several students volunteered considerable time reviewing and helping to edit portions of the Freshman Handbook.

The final report of the F.A.C. Steering Committee became available as the year drew to a close. The Committee, consisting of Dean Peter Büttner, Professors Robert Halfman and Margaret MacVicar, Kevin Miller, Class of 1977, and Professor Hartley Rogers, Chairman, was formed in 1975 and charged with reviewing the structure, policies, and effectiveness of the freshman advisory system. In its report the Committee basically endorsed the various operational and policy changes that have evolved over the past nine years and found the system to be in substantially good health. The Committee's formal recommendations were, briefly, as follows:

- 1) That the Institute establish the position of Director of the Office of Freshman Advising, which would replace the current position of Executive Officer of the Freshman Advisory Council. The position of faculty chairman of the Freshman Advisory Council would not be re-established.
- 2) That a Committee on Freshman Advising (C.O.F.A.) be established, initially as an ad hoc presidentially appointed committee. The Committee's primary responsibilities would be "to advise and assist the Director of the Office of Freshman Advising, to become and remain informed concerning the first year undergraduate educational program and, in light of this information, to formulate and review the policies in connection with the operations of the Freshman Advisory System, the role of advisors in the first year program, recruitment of new advisors, and relations with advisors, departments, faculty, and students."
- 3) That the name "Freshman Advisory Council" be retained for the collection of freshman advisors and associate advisors serving in the freshman advisory system.

4) That the faculty and administration of the Institute "accept and endorse (the report of the Steering Committee) and conclusions previously listed (in their report), and that, in so doing, they affirm that participation in freshman advising, like participation on faculty committees, is a valuable and essential part of Institute-wide academic service and that such participation as an advisor should be appropriately recognized by each department in its assessment of an individual's academic responsibilities. "

Members of the F.A.C. Steering Committee, particularly when they discussed their report with the Committee on Educational Policy, noted the desirability of a suitable forum for the discussion of a range of academic and other issues affecting first-year students. They observed that Dean Robert Alberty has provided such a context for the faculty teaching science core subjects, but that some topical areas such as grading, computer programming, and the total mix of General Institute Requirements transcend the formal boundaries of the School of Science. Several such issues, including pass/fail grading, will arise within the next year and there is merit in having a focus for discussion which includes the perspectives of advisors and the F.A.C. staff. Although not formally proposed as a charge for the C.O.F.A., such discussions would seem reasonably within their scope.

Dean Büttner will be on leave during the coming year, attending the Accelerated Master's Program at the Sloan School of Management. A process has been initiated to identify his replacement. Until a successor to Dean Büttner is appointed, Dean Bonny S. Kellermann will continue with her responsibilities and assume those required to continue the smooth functioning of the office. Susan Baram and Marie-France Pierre continue to job-share the principal secretarial position and Elizabeth Pierce was hired to replace Patricia O'Neill who left in September 1976. Ms. Pierce provides secretarial support for both the F.A.C. and the Undergraduate Seminar Program. Rosebeth Rosen, Class of 1978, and William Harper, Class of 1979, joined John Marcou, Class of 1978, as student employees working part-time during the academic year and full-time during the summer.

PETER BUTTNER
BONNY S. KELLERMANN

Undergraduate Seminar Program

Once again the Seminar Program has continued to show increased interest from students. Fifth-week registration in the fall term showed 854 students (632 first-year and 222 upper-class) registered for undergraduate seminars. This is an all-time high, an increase of 29 students over last year's previous all-time high. The fifth-week enrollment in spring term seminars also was a record high of 676 students (384 first-year and 292 upperclass), showing an increase of 31 students over the previous year.

The number of seminar offerings held constant at 63 for the fall term; the spring term, however, dropped down to 42 seminars.

A discussion was held with the Committee on Curricula on offering undergraduate seminars for other than six units of credit. One seminar planned for fall, 1977 will be given for three units of credit.

A survey was conducted of undergraduate students' attitudes toward the seminar program. This survey confirmed that the program continues to be an important and popular component of the M. I. T. undergraduate education.

This has been Professor Ernest Cravalho's last year as faculty chairman of the seminar program; I will continue as executive officer.

BONNY KELLERMANN

Undesignated Sophomore Program

The number of sophomores choosing to be undesignated continued the somewhat erratic downtrend of the past few years with 170 registered at the beginning of the 1976-77 fall term and 101 in the spring. Typical numbers several years ago were 220 and 120.

The program continues to match students with advisors who numbered about 80 and are quite similar in range of experience and status to the freshman advisors. Low-key support is offered to students and advisors, especially in case of end-of-term difficulty, from a base in the counseling section of the Dean's Office.

ROBERT L. HALFMAN

Office of Preprofessional Advising and Education

The Preprofessional Advising and Education Office scheduled several meetings during the past year for students interested in medicine and law. These meetings continue to be an effective way to provide information to students. Early in September, meetings with first-year students acquainted them with the advisory services of the Premedical and Prelaw Councils as well as the services available from the Preprofessional Advising and Education Office. Later that month Dr. David Scotch, Associate Dean of New York University Medical School, spoke with medical school applicants about the nature and format of the medical school interview. In February, sophomores were told of the planning necessary for a premedical education. Later that month, members of the Committee met with students who will be attending medical school next year to discuss the criteria for selecting medical schools. Meetings were held in April for students applying for admission to medical and law school for the class entering in September 1978. The change in the format of the Medical College Admission Test was the topic of another meeting to acquaint our students with the nature of these changes.

Representatives from five medical schools, 13 law schools, one school of public administration, and one school of health administration visited M.I.T. during the year. Students find these meetings informative and helpful in determining the schools to which they will apply.

Professor J.D. Nyhart, Chairman of the Prelaw Advisory Council, attended the June meeting of the Northeast Association of Prelaw Advisors at Haverford College in Pennsylvania. Professor B.S. Gould, Chairman of the Premedical Advisory Council, attended the meeting of the Northeast Association of Advisors to the Health Professions in Boston in April. The contacts made at these meetings both with other advisors and with professional schools provide an opportunity for mutual support. Professor Gould also attended the annual meeting

of the Association of American Medical Colleges in San Francisco in November 1976, and visited four medical schools in California. These visits helped increase his understanding of their admissions processes, while allowing him to present information on the breadth of undergraduate education at M. I. T.

Dean Susan Houpt organized an informal gathering for women premedical students at the home of Dean Carola Eisenberg. Women physicians, medical students, and premedical students were invited to share their thoughts about the medical profession.

The Preprofessional Advising and Education Office sponsored or cosponsored a number of offerings during I. A. P. These included:

- 1) The Medical Profession Today, at which a number of couples with dual medical careers discussed their lives and career patterns;
- 2) A Brief Introduction to the Law, cosponsored with Professor Jeffrey Meldman;
- 3) Take Me to Court, cosponsored with Professor Michael Lipsky;
- 4) Workshop for Women Students on Career Planning, cosponsored by the Association of Women Students and the Women Faculty;

In the spring we mailed a questionnaire to the 440 alumni who are currently attending medical school; more than half were returned. The respondents shared their thoughts and observations about medical education and, particularly, their own medical schools. Information from our alumni continues to be invaluable to students as they plan their medical studies.

During this past year Dean Houpt assigned 86 members of the class of 1979 to members of the Premedical Advisory Council. She expects that more members of this class will come to her in September for assignment to an advisor. The number of students who are interested in medicine has continued to be approximately 10 percent of each class.

At their request, Dean Houpt became the advisor to the Association of Black Premedical Students. The group held several bake sales during the year to raise money for the support of delegates to the annual meeting of the Student National Medical Association. Three attended this year's meeting.

PREMEDICAL AND PRELAW STATISTICS

A total of 144 individuals applied to medical, dental, or veterinary schools for admission in 1977. Admission to at least one school was obtained by 71 (81 percent) of the 88 S. B. candidates; and 28 (50 percent) of the additional 56 applicants were admitted.

Altogether the 144 applicants submitted 2,392 applications to 112 medical schools, a mean of 17 per student.

Ninety-nine applicants received 243 acceptances from 65 medical schools. The mean number of acceptances was 2.5 among the students who received acceptances. The ratio of acceptances to applications was 10 percent.

Eight citizens of foreign countries applied to medical schools in the US. Six were admitted.

Minority Student Support

Thirty-six of the accepted applicants (36 percent) were accepted to only one school. Twenty-two of these were accepted only by their state school (23 percent of the total number of applicants accepted).

Ninety-six applicants are attending 45 medical schools; one has decided not to attend and two have deferred their acceptances for one year.

Twenty-four of the applicants had failed to gain admission to medical school in a previous year; 14 were admitted (58 percent).

Thirty-one alumni of M.I.T. applied to medical school through the Preprofessional Advising and Education Office. Eighteen (58 percent) were admitted. Of the 13 alumni who applied to medical school for the first time, 7 (53 percent) were admitted.

Forty-seven undergraduate and graduate students and 27 alumni who graduated between 1940 and 1976 applied to law school for admission in 1977. They submitted 367 applications to 58 law schools. The average number of applications was 6. Thirty-five (74 percent) of the S.B. candidates and graduates and 14 (52 percent) of the alumni were admitted to law school.

A total of 39 individuals will be attending 18 law schools.

Seven (18 percent) of the S.B. candidates who were admitted to law school decided not to attend. One alumnus was accepted but chose not to attend.

We received 58 LSAT scores for 47 students who applied to law school this year. The mean score is 690.68 for those applying. We received 20 LSAT scores for 27 alumni who applied to law school this year. The mean score of those applying is 706.15.

SUSAN HAIGH HOUP T

Minority Student Support

Support activities for minority students continue to be a viable segment of the Dean for Student Affairs Office program. The activities are designed to enrich the social and educational experiences of minority students.

The operational objectives of the support activities are:

- 1) to help prevent "crisis" situations;
- 2) to develop social attitudes and behavior that promote positive self-concept and achievement motivation, thereby increasing grade point average and decreasing the attrition rate;
- 3) to increase social awareness and involvement in campus activities;
- 4) to decrease the number of interpersonal conflicts in dormitories and other areas;
- 5) to increase cultural awareness in the university and local community thereby decreasing ethnic cultural genocide;

6) and to increase contact with highly motivated minority and other concerned persons who serve as role models.

I have continued this year to invite students, individually or in large or small groups, to breakfasts, luncheons, and dinners, and have arranged retreats, talk sessions, seminars, lectures, and conferences. Student-faculty departmental groups and ethnic-national-international groups also have been initiated and encouraged to help provide a format for personal interactions and cultural growth.

Specific activities are the Undergraduate Minority Women's Group, an outgrowth of this called the "Minority Women's Group," an I.A.P. project, and the Black Student Conference on Science and Technology.

The Undergraduate Minority Women's Group was an outgrowth of the 1976 Spring Retreat held at Talbot House in Woodstock, Vermont. The concerns of minority undergraduate women were addressed there and, subsequently, several seminars were held. Among the guest speakers were Dr. Leon Eisenberg, the Maude and Lillian Presley Professor of Psychiatry, Harvard University Medical School; Dr. Chester Pierce, Professor of Psychiatry and Education, Harvard University; Dr. Carola Eisenberg, Dean for Student Affairs, M.I.T.; and Mrs. Tamao Denniston, Professor of Education, Boston State College. The Group selected Tutoring Plus as their community service project. Plans are under way to augment current resources by improving the maintenance of its present area, providing tutoring and recreational assistance, and replenishing appropriate library supplies. The participants held several bake sales to secure funds for this service project and were deeply gratified by the experience of providing a needed service to others. The Group also established communications with undergraduate minority women at Radcliffe and Wellesley colleges.

Because of the success of the Undergraduate Minority Women's Group, a Minority Women's Group was coordinated by Myra Rodrigues, Social Worker, M.I.T. Medical Department; Muriel Birchette, Special Lecturer, Division for Study and Research in Education; and Mary Hope, Assistant Dean for Student Affairs. Three two and one-half hour sessions were held biweekly to provide an opportunity for all minority women at M.I.T. to discuss their concerns and special problems. Refreshments were provided by the Offices of Minority Education, Assistant to the President and Chancellor for Minority Affairs, Dean of the Graduate School, and Dean for Student Affairs.

Concerns about the attrition rate of minority students and their development of a realistic expectation of M.I.T. were expressed by Professor Alan Lazarus, Senior Research Scientist, Department of Physics. Professors Lazarus and Wesley Harris and Deans Eisenberg and Hope met to discuss ideas and suggestions for assisting minority students. The discussions resulted in an I.A.P. project seminar called Changes We Go Through as Black Students Trying to Succeed at M.I.T., the title suggested by Leslye Miller, Class of 1978, a Chemical Engineering student. Three discussion meetings were held during January 1977. The topics included "Student-Student Interactions," "Student-Faculty Interactions," "Financial Management," "Time Management," "Course Planning," "Study and Research Information," and "Tips on the Proper Use of the Libraries." Speakers included: undergraduate and graduate student panelists; Sylvia McDowell, Librarian, Student Center Library; Nelson Armstrong, Associate Director of Financial Aid and Director of Student Employment; Professor Harris, Director, Office of Minority Education; and Dean Hope, Assistant Dean for Student Affairs. Moderator for the session was James Harrington, Class of 1978, a Mechanical Engineering student. At least 75 students participated at each of these discussions, and at the request of the students, several sessions were held during the spring term.

The Black Student Conference on Science and Technology was held at M.I.T. on April 22 and 23, 1977. The theme of the Conference was "Economic Development in a Technological

Minority Student Support

Society -- Applications of Technical Expertise." Added dimensions to this year's Conference were the programs for local high school students and admitted first-year M.I.T. students, and the Career Seminars. The High School Program, coordinated by William Marable, Class of 1978, and Gail Wilson, Assistant to the Director of Admissions, included invitations to 40 local high school students selected by high school guidance counselors and 30 incoming first-year students to participate in the Conference. This program was funded through the Office of Admissions. The career seminars, sponsored by 14 business and industrial corporations, the United Nations, the United States Department of State, the Foreign Service, and the Massachusetts Executive Office of Environmental Affairs, was coordinated by Robert Weatherall, Director, Career Planning and Placement Office. The goal of the Conference was to provide information on the opportunities for black professionals in government, academics, and the private sector, and to illustrate the opportunities for application of technical and professional skills for community needs and services. Guest speakers at the Conference were: The Honorable C. Delores Tucker, Secretary of State of the Commonwealth of Pennsylvania; Henry Hill, Class of 1945, President, Riverside Research Laboratories; Anthony Davis, President, Davis Associates, Dallas, Texas; Professor Frank Jones, M.I.T. Department of Urban Studies and Planning; The Honorable Jessie Rattley, vice mayor, Newport News, Virginia; and the Honorable Theodore Britton, US Ambassador to the Caribbean Islands. Fourteen minority M.I.T. alumni and five M.I.T. professors participated in the program as panelists and speakers. Student Cochairpersons of the Conference were Paul Woods, Kenneth Armstead, James Harrington, William Marable, and Yolanda Hinton.

Students used this occasion to recognize those persons whom they felt had rendered meritorious and dedicated contributions to their well-being. This year's recipients of service plaques were Julia McLellan, Associate Director of Admissions and Robert K. Weatherall, Director of Career Planning and Placement. Several meetings were held to discuss the special needs of and to provide assistance to Spanish American and Mexican American students. One result of these meetings was the Student News Bulletin. Also, specific plans were made to engage more student participation in campus activities.

The departmental student groups continue to progress. The Black Student Electrical Engineers, advised by Professor Arthur Smith, continue to serve as tutors and to assist in planning many varied extracurricular activities. This year the group also assisted in generating the Minority Student Resume Booklet, edited by Kimberly Ann Francis, Class of 1978. Other active groups are Black Mechanical Engineers, Premedical Students, and Chemical Engineers. The M.I.T. Gospel Chorus and Black Student Christian Fellowship continue under excellent student leadership.

The Albert G. Hill Prize is awarded to the minority student in his/her junior or senior year who has made continued contributions to the improvement of the quality of student life for minorities at M.I.T. while satisfactorily progressing academically. The recipients for 1977 are Yolanda Hinton, Class of 1977 and Kimberly Ann Francis, Class of 1978. Members of the Hill Award Committee are Dr. Albert G. Hill, Director, Plasma Fusion Center; Professor Jones, Department of Urban Studies and Planning and Director, Minority Intern Program; Dr. Robert S. Kennedy, Professor, Department of Electrical Engineering and Computer Science; and Dean Hope.

A total of 30 minority students received undergraduate degrees during the 1976-77 academic year.

Efforts are being made to retrieve those minority students who have received negotiated withdrawals. Such students experience difficulty achieving academically because of financial problems, family concerns, and adjustment and maturation difficulties. With the assistance of Robert Newell of the Digital Corporation, several students have been given employment full-time during the summer, and part-time while attending classes at Northeastern University, Boston University, and M.I.T. Courses are financed through Digital Corporation benefits.

Evaluation of minority support activities is continual. Programmatic techniques such as interviews, informal surveys, follow-up of student social and academic activities, monitoring of student and university community participation in activities, and communication with visitors and alumni are used to assess the needs, effectiveness, and quality of the programs.

To contribute to my professional growth, I attended a conference on counseling minorities held at Michigan State University, Lansing, Michigan, sponsored by the Urban Counseling Mental Health Program in cooperation with the College of Education, College of Urban Development, College of Human Medicine, Dow Chemical Company, College Entrance Examination Board, and Continuing Education Service, Michigan State University.

I wish to express my gratitude to Peter Richardson and Julia McClellan of the Admissions Office, Nelson Armstrong and Dorothy Bowe of the Financial Aid Office, Robert Weatherall and Phyllis Jackson of the Career Planning and Placement Office, John McNeill, Student Center Food Services, and Jane Brandford and Joanne Murray of the Office of the Dean for Student Affairs for their support, cooperation, and exemplary service to minority students. Without their support many activities would not have been as successful as they were.

MARY O. HOPE

Women's Program

Having joined the staff of the Office of the Dean for Student Affairs in December, I spent the first month and a half meeting people and learning more about the workings of M. I. T. Just before the beginning of the second term I started seeing students on a regular basis, and since then my time has been divided among counseling, other Dean's Office activities, and providing direct support for women students.

One of my primary support activities is to act as an advisor to the Association for Women Students. Their activities this spring have included: sponsoring a lecture by Elaine Noble, Massachusetts State Representative; helping to sponsor, with Women in Science and Engineering (WISE), a debate on the value of single-sex vs. coed education for women who want to be scientists; and concentrating on efforts to recruit more women students to M. I. T. These have involved: 1) writing to those women who filed preliminary applications for admission but who then did not follow up; 2) assigning students to the Admissions Office to be available to speak to applicants and their parents when they come for interviews; and 3) writing letters to all admitted women students, urging them to come to M. I. T.

In addition, I have participated in other admissions related activities. In May the Admissions Office and the Dean's Office sponsored a half-day program for women sophomores and juniors from high schools in the greater Boston area. The first part of the afternoon was devoted to a panel composed of "fresh-women," upper class students, and alumnae discussing their experiences in getting a scientific and technical education and the job opportunities open to them. After questions, the students divided into groups to visit various faculty labs and research operations. A program is now under way to evaluate the current efforts in women's admissions and to analyze the strengths and weaknesses of the present attempts to increase the number of women at M. I. T.

Work with graduate women is organized primarily by Dean Jeanne Richard of the Graduate School Office. In the spring this office participated in planning the program which included

Advising and Counseling

discussions on "Changing Careers," "Counseling and Support Groups," "Is There a Social Life at M. I. T. ?", and "Single? Married?"

In several areas, my efforts have just been preliminary. Initial activities, which will require a lot of follow-up, include disseminating job and career information to women students, stimulating discussions on the effect of the women's programs on men and the need for support of male students, and arranging regular meetings with other women at M. I. T. who are providing support for students in order to coordinate these efforts.

Finally, I am serving on the Joint Committee of the Wellesley-M. I. T. Exchange Program and am a member of the Dean's Office housing group with particular interest in those issues affecting women students.

HOLLIDAY C. HEINE

Advising and Counseling

This academic year began with the loss of two staff members and a search to replace only one of them. The reduction in staff personnel and the amount of time involved in the successful search for a successor to former Assistant Dean Anne Thompson made it necessary for the three continuing members of the Section to reduce considerably the scope of their involvements. Efforts were spent primarily in responding to the needs of individual students and supporting educational and student related groups directly connected with counseling. In November, Dr. Holliday C. Heine was appointed Assistant Dean to work in the counseling section and to support women students and their programs. The Section was extremely enthusiastic about the wealth of abilities, experiences, and ideas which she brought to the group in December.

In November, sectional goals and priorities for 1976-77 were presented to Dean Carola Eisenberg and the staff at an all-day meeting at Endicott House. The priorities were: 1) adjustment to personnel changes and reductions; 2) examination of our relationships and communications with faculty and staff members; 3) reexamination and understanding of "D. S. A. (Dean for Student Affairs) counseling;" 4) finding a name to replace "counseling section;" 5) reexamination of readmissions, withdrawals, and other administrative tasks; and 6) continued secretarial development.

Second-level goals were: 1) exploring ways of improving student-student resources; 2) developing seminars, I. A. P. programs, etc. for groups of students with particular interests and problems; 3) developing a user-feedback or evaluation mechanism; 4) improvement of professional skills; and 5) expansion of our research and data collection.

The Section participated in Office discussions about emergency procedures involving severe illnesses, missing students, and deaths. This exploration proved extremely useful during the fall term which had an uncharacteristically high number of severely ill or critically injured students.

By January, the group was able to expand its scope of activities. Along with Deans Peter Büttner and Bonny Kellermann of the Freshman Advisory Council (F. A. C.) and Dean Eisenberg, the group examined its premises and written materials about readmissions. This review included assessment of the D. S. A. 's policies on readmission of those students who

had been previously voted a negotiated withdrawal and who were again, due to unsatisfactory performance, required to leave the Institute in February. The review convinced the group that its basic philosophies and guidelines on readmissions did not require changes. However, we had learned that the readmission literature and application materials required modification and updating. During these discussions, it was decided not to recommend official leave of absence status for certain former students.

Very thoughtful and critical discussions were held on the sharing of information about students with members of the M.I.T. community and parents. The complexities of this important issue were appreciated by all. The need for further understanding and clarification of the issues remains. During the next academic year, the group hopes to assemble some materials for the office and for possible broader distribution.

The members of the Section remained quite involved in Dean's Office and Institute committees. All members of the Section, later in the year joined by Dean Kellermann, had weekly meetings with the Associate Director of the Psychiatric Service, Peter Jenney, and, as time permitted, with Dr. Albert Samaraweera and two psychiatric fellows. The full Section participated with the Committee on Academic Performance (C.A.P.) in reviewing the grades of students, handling petitions, and deciding on policy matters. Deans James Bishop and Robert Halfman were members of the D.S.A. Associate Deans group. Deans Bishop and Heine were part of the D.S.A. Housing group, the weekly luncheon meetings with graduate and faculty residents, and the monthly dinner meetings with faculty residents. These cooperative working relations between the Counseling Section, D.S.A. housing administrators, and graduate and faculty residents enable the Section to be aware of emerging issues in the students' academic and residential lives and reenforce the Institute's superb multifaceted approach to aiding, advising, and supporting its students. Dean Halfman chaired a D.S.A. committee on relationships between students, faculty, staff, and the D.S.A. From this committee came a well-received proposal for D.S.A. "forums" on issues of widespread concern and interest to members of the community. Dean Heine was selected to chair the task force for implementing this proposal. Dean Halfman also was a member of the Steering Committee which evaluated the F.A.C.'s operations. Deans Bishop and Hope continue to serve on a Special Assistant for Minority Affairs Office Committee dealing with student related issues. Dean Bishop served as an ex-officio member of the Committee on Graduate School Policy, and as a member of the I.A.P. Policy Committee which in its report to the faculty made a strong recommendation that I.A.P. continue as a major component of the academic calendar and program.

Through Joanne Murray's coordination, the Section has continued its tallying of "counseling conferences." During 1976-77, 1,620 conferences with students, 490 brief conferences with students, and 380 non-student conferences about individual students were held. These figures do not include meetings with the Psychiatric Service, the C.A.P., staff meetings, and interactions with students on programs such as the Black Student Conference on Science and Technology and the Association of Women Students. Twenty percent of the student conferences were held with women, 20 percent with minority group students, and five percent with foreign students. In spite of the efforts made by the Dean's Office to acquaint graduate students with D.S.A. counseling services, the percentage of graduate students seen in counseling declined from 11 percent of the total visits last year to six percent. Distribution of student conferences by schools was: Engineering, 46%; Science, 32%; Humanities and Social Science, 7%; Management, 7%; Architecture and Planning, 4%; undesignated sophomores, 4%. The distribution of student conferences by year was: first year, 9%; second year, 20%; third year, 28%; fourth year, 21%; fifth year 2%. Fourteen percent of the student visits were by non-registered individuals. Most prevalent reasons for the students' visits to the counseling section were for readmissions, technical readmissions, and readmission consultations (20%), academic difficulties (18%), withdrawal and withdrawal consultations (14%), and C.A.P. actions (8%).

Kay Hudock, a graduate student in the Sloan School of Management and a former secretary of the Section, worked during the spring term on the completion of a withdrawal study started in the early 1970s. The data and conclusions of her report will be available during the next academic year.

JAMES J. BISHOP

Student Community Affairs, Student Activities, and Governance

In reporting on Student Community Affairs two themes that have developed noticeably this year should be stressed. The first is the increasing number of social events being sponsored both by undergraduate and graduate students, and the second is the increasing interest expressed by a variety of sources concerning the quality of student life.

The Class of 1978 and the Class of 1979, this year for the first time in recent years, sponsored semi-formal dances for class members and the community. The graduating Class of 1977 also continued the innovation of the Class of 1976 in presenting a formal dance in Morse Hall at the end of the examination period for members of the class, friends, and guests. The Graduate Student Council sponsored four dances during the year, the graduate residences two, and the Black Graduate Students' Association one. Following the spring break the Undergraduate Association and the Student Center Committee sponsored a series of Friday afternoon concerts on the West Plaza. Together with the ongoing and developing programs of the undergraduate residences, the Interfraternity Conference, the Student Center Committee, the International Students Association, the Black Student Union, and other community components, it would appear that this form of activity is at a new level.

The Undergraduate Association, the Graduate Student Council, the Committee on Student Environment, the Committee on the Visual Arts, and the Corporation Joint Advisory committees, each in its own way has been increasingly concerned with questions of the student environment and/or the quality of student life.

During the year the Undergraduate Association sponsored open forums on the topics of finances, housing, evening classes, and quizzes. A forthcoming Graduate Student Survey compiled by the Graduate Student Council will add fresh information to these and other considerations.

The program of orientation for new graduate students, organized by the Graduate Student Council, was the most comprehensive in its three-year history. Particularly helpful was a videotaped series portraying the people and objectives of the major student support services. This program was scheduled for cable viewing several times during the early days of the term and at other times during the year.

The several standing committees of the Undergraduate Association continued to perform their functions capably. Significant organizational and program initiative, however, was taken by the Interfraternity Conference, the Dormitory Council, the classes, and the International Students Association.

The approximately 100 student activities recognized by the Association of Student Activities and the Graduate Student Council continue their beneficial services to individuals and to the community. The Student Art Association and the Hobby Shop report increased enrollments. The Folk Dance Club has had an unusually successful year, as has the Chinese Student Club and Sangam, the Indian Students Association.

Program space in Kresge Auditorium, the Stratton Student Center, Walker Memorial, and Burton-Connor Dining Hall continues to be scheduled at prime-time capacity. Thanks to the good will and understanding of the community users and the heroic efforts of the Physical Plant operating staff most projected programs can be accommodated, although frequently with compromises. Space utilization continues to be a major concern of the Student Center Committee Scheduling Officers and of the Association of Student Activities executive committee.

The M.I.T. Chapel was in use for six christenings, 14 memorial services, 51 weddings, 417 scheduled religious services, and 28 musical and theatrical programs. The Reverend John Crocker, Jr., Episcopal Counselor here since 1969, will become rector of Trinity Church, Princeton, New Jersey in September. He leaves with us the enduring legacy of an informed ministry. Our profound thanks and best wishes go with him.

ROBERT J. HOLDEN

Fraternities and Independent Living Groups

The 1976-77 academic year may in the future be viewed as a watershed year for fraternities and independent living groups at M.I.T. There has been an exponential upswing in interest and activity within the fraternity system. The major elements which characterize this trend are: a growing awareness that the fraternity brotherhood extends beyond the walls of any given house and encompasses the entire system, an interest in working with and learning from other fraternity systems, a strong effort to create new programs for the benefit of all fraternities at M.I.T., a major concern for safety and long-range facility planning for fraternities, and a progressive, constructive attitude.

In response to interest expressed by several M.I.T. students and other national fraternities, a lively discussion has begun within the Interfraternity Conference (I.F.C.) on the topic of expansion. Two new independent living groups opened this year, Alpha Delta Phi and the Women's Independent Living Group.

Interfraternity Conference leadership, under the very capable direction in the fall of Richard Maebius, Class of 1977, and in the spring of Steven Piet, Class of 1978, has been outstanding. Currently one of the most active and effective student organizations on campus, the I.F.C. has made considerable progress in the areas of cooperative buying, educating Rush Chairmen through workshops and technical assistance, and organizing fraternity summer housing. Long-range facility planning, community relations, and alumni relations are areas in which progress has been made and which will receive a great deal of attention during the coming year. The entire Executive Committee of the I.F.C. is deeply involved in working with houses across the system while at the same time seeking to avoid conflict of interest by viewing themselves first as members of the I.F.C. Executive Committee and second as members of their own houses.

The Alumni Interfraternity Conference (A.I.F.C.) became more active as it obtained a new chairman and a new administrator. Daniel J. Holland, Class of 1958, was appointed chairman in October 1976, and Merrick J. Leler, Class of 1974, was appointed administrator. In addition to his normal staff responsibilities as Assistant to the Superintendent of Buildings, Mr. Leler's A.I.F.C. responsibilities are to assist fraternities and alumni corporations in making physical improvements in the houses and to stimulate and coordinate long-range planning efforts. Mr. Leler's position with Physical Plant places him in an excellent position

to provide the Houses with quick, effective advice and assistance on their physical facilities. In addition to working with individual houses and contributing to I. F. C. activities, Mr. Leler also has been engaged in developing a program for the installation of automatic sprinkler systems in fraternity houses. This program, coupled with the possibility of a more cost-effective insurance program for houses which install sprinklers, has the full support of the Office of the Dean for Student Affairs, the A. I. F. C., and the I. F. C. An effort already has begun to encourage houses to install such systems.

The key fraternity event of the year was the I. F. C. -A. I. F. C. Fraternity Symposium on February 12, 1977. This afternoon event, attended by about 200 undergraduates and alumni, consisted of talks by Chancellor Paul E. Gray, Class of 1954 and Dr. George S. Dirghalli, Grand High Gamma of Lambda Chi Alpha, and three workshop sessions on issues ranging from physical facilities and safety, to Rush, pledge training, and brotherhood. The Symposium has been discussed widely across the campus as an important and useful event that contributed much to the growing attitude in the fraternities that there is great value in working with and knowing people in other houses. The inspiration behind the Symposium was that of David Dobos, Class of 1977, who had previously served as I. F. C. Treasurer and Judicial Committee Chairman. It is through the efforts of Mr. Dobos, with support from Mr. Leler, that the Symposium was such a success.

In August, the upperclass men and women who for several months had worked to start two new independent living groups began to move into the building at 351 Massachusetts Avenue. Alpha Delta Phi fraternity and the Women's Independent Living Group conducted successful rushes and successfully weathered their first year in existence as living groups. Renovations on the remainder of the building are going well; both groups expect to reside in their own houses for the beginning of the 1977-78 academic year.

For a year marked by such achievement and ideals for the future, the 1976-77 academic year began on a slightly less than optimistic note for the fraternity system. Rush Week saw 357 pledges, the lowest total number of pledges since 1965. About half of the houses went under their pledge targets although most were under by only one or two. While part of the reason for a low pledge total seemed to be lower pledge targets (greater retention of upperclassmen in the houses being the reason for this), the small Rush was a matter of concern for the I. F. C. and most other observers. Because most houses were close to their pledge targets, no house felt major economic ramifications from the low Rush. However, this incident has caused the I. F. C. and the fraternities to reexamine Rush and to begin working together to see that no house suffers a substandard Rush in future years. The fraternity population for the 1976-77 academic year was 1,298, an increase from 1,267 the previous year (the two new houses accounted for 38 members). This represents an average house size of 40. Of the 32 houses, nine are located in Cambridge, two in Brookline, and the remainder in Boston's Back Bay and Fenway areas. In November the "Guide to Safety, Health, and Construction Codes Applicable to M. I. T. Fraternities" was released by the Dean for Student Affairs Office to fraternities and their corporations. This guide was the result of efforts of student and staff members over the past year and a half, and includes relevant sections from the state building code and other codes which affect fraternities.

Fraternities at M. I. T. began looking outside the Institute this year and the I. F. C. has expressed strong interest in hosting a regional interfraternity conference meeting in the Boston area in the coming year. During this year James Bidigare, Class of 1978, and David Soule, Class of 1979, attended, along with Dean Kenneth C. Browning, the National Interfraternity Conference Bicentennial meeting in Williamsburg, Virginia. In addition, Mr. Bidigare and Scott Golden, Class of 1978, attended the Mid-west Interfraternity Conference in Kansas City, Missouri. The contacts made at these conferences have provided many insights into the operation of fraternities and interfraternity conferences on other campuses and have helped to broaden the horizons of those who attended and, through them, of the entire system.

The Frederick Gardiner Fassett, Jr. Award, which recognizes "spirit, dedication, and service to the M.I.T. Fraternity Brotherhood" was awarded by the I.F.C. to Mr. Maebius and Mr. Dobos.

KENNETH C. BROWNING

Institute Houses

The 1976-77 academic year saw no additions to the capacity of the Institute House System. However, when Bexley Hall reopened for the fall, there were marked improvements, the result of the summer's rehabilitation project which renewed bathrooms and kitchens, utilities, and repaired and painted the walls.

In September, 1,040 freshmen arrived and when they were housed at the end of Residence/Orientation Week, we found ourselves with the greatest crowding we have experienced: 100 extra people in the system. It was initially anticipated that this number would be close to 150, but the smaller-than-expected size of the freshman class resulted in the lower number. The care and energy which the house governments and faculty and graduate residents put into dealing with students in each of the houses minimized the number of serious problems which resulted from the overcrowding. However, we did experience a greatly reduced flexibility to move students in order to solve roommate conflicts. As usual, very few college transfer students were afforded housing due to the extreme overcrowding and the necessity to house freshmen. This year, we placed 80 percent of the freshmen in their first choice house and another 5 percent in their second choice. The final residential distribution of freshmen was as follows:

	MEN	WOMEN	TOTAL
Institute Houses	529	145	674
Independent Living Groups	331	19	350
Off-Campus (Commuters, etc.)	<u>13</u>	<u>3</u>	<u>16</u>
TOTAL	873	167	1,040

The overall residential distribution of undergraduate students for the fall term was as follows:

Institute Houses

RESIDENTIAL DISTRIBUTION OF M. I. T. STUDENTS

Fall Term 1976-77

Institute Houses	<u>MEN</u>	<u>WOMEN</u>	<u>TOTAL</u>
Single-sex Housing	710	225	935
Coed Housing, but not Coed Floor	350	-	350
Coed Housing	<u>742</u>	<u>288</u>	<u>1,030</u>
TOTAL INSTITUTE HOUSES	1,802	513	2,315
Fraternalities and Independent Residences			
Boston Single-sex (20)	820	-	820
Coed (1)	22	10	32
Cambridge Single-sex (7)	250	16	266
Coed (2)	50	29	79
Brookline Single-sex (1)	68	-	68
Coed (1)	<u>25</u>	<u>11</u>	<u>36</u>
TOTAL FRATERNITIES, ETC.	1,235	66	1,301
TOTAL "ON-CAMPUS"	3,037	579	3,616
TOTAL "OFF-CAMPUS"	<u>694</u>	<u>158</u>	<u>852</u>
TOTAL UNDERGRADUATES	3,731	737	4,468

This year saw the continued development of more mature, stable governments in many of the Institute Houses and an enhanced social program in most houses. Judicial issues came to the forefront due to a series of cases arising in an Institute House which resulted in appeals to the Dormitory Council Judicial Committee. Better definition and communication of judicial procedures within the Institute House system should be a major agenda topic for future years. This does not imply that incidents of the past year were not handled adequately but that the process in general could be better defined and students could be better informed.

This spring saw an unusual amount of activity in the Institute Houses on the part of Health Inspectors from the City of Cambridge. A number of safety and health issues, especially that of cooking in student rooms, were brought to our attention. With cooperation from residents of Institute Houses and from the housing staff, most problems were dealt with and the system is better off as a result of an increased awareness.

The demand for graduate student housing continues to increase with Ashdown House and Tang Residence Hall being effectively full all year as was the case with married student housing. The residential distribution of regular graduate students in the fall term of 1976-77 was as follows:

On-campus Single Students	775
On-campus Married Students	390
Graduate Residents in Institute Houses	52
Graduate Residents in Fraternities	5
Off-campus	<u>2,552</u>
TOTAL	3,774

The residential system continues to be a focus for much of the social life on campus, a strong element in the student support services on campus, and a major factor in the socialization of undergraduate students. We are pleased that housing retention rates for upperclass students remain quite high even though this reinforces the housing shortage. We continue to support the housing guarantees for first-year students and the guarantee of eight contiguous terms of residence for undergraduates in the house. After a good year, the housing system looks with apprehension to the increased crowding which will be necessary to accommodate the incoming Class of 1981.

Faculty and Graduate Residents Program

The Faculty and Graduate Residents continue to play a role which is at once visible and subtle in seeking to improve living conditions in the Institute Houses and to help individuals and groups that are in need. As has been the case for the past several years, fraternities also participate in this program. This year, six fraternities had tutors. The role of the fraternity tutor differs from that of the Institute House Graduate Resident because of the already existing supports and program-generation responsibilities which are inherent in the fraternity structure; however, most houses which have had tutors feel very positively about the role which they have played. The Non-Resident Student Association also has a graduate resident.

We were pleased to welcome to the program this year Professor Borijove Mikic of the Department of Mechanical Engineering, and his wife, Liba, who became the Senior Faculty family in residence in Senior House on April 1, 1977. Professor Ronald Prinn of the Department of Meteorology, and his wife, Jane, left Baker House where they had served as Junior Faculty Residents for three years. For 1977-78 they will not be replaced by another Junior Faculty Resident; instead, a married graduate resident couple already in Baker House will occupy that apartment. Professor Robert Channon of the Department of Humanities, who has for eight years been associated with Russian House, is leaving for one year to accept a research grant in the Soviet Union. At this writing his replacement has not been found.

This year, in response to the concern expressed in spring, 1976, a flyer better defining both the role of Graduate Residents and the selection process was distributed to prospective Residents. We continue to upgrade our training and orientation for Graduate Residents; in addition to the regular fall orientation which will occur in September, a well-received training session for new Graduate Residents was held in the spring.

KENNETH C. BROWNING
ALICE M. SEELINGER

Talbot House

Talbot House has continued to enjoy popularity with a variety of groups from the M. I. T. community. During 1976-77 we have had 58 groups comprised of over 1,175 individuals stay at Talbot House. These can be categorized as academic groups (26 visits), clubs (18 visits), and living groups (14 visits).

Talbot House continues to be fully booked during the winter ski months. It also has been occupied during the weekends of the spring, summer, and fall. In the past we have relied on word-of-mouth for our Talbot House reservations. On several occasions advertisements have been placed in The Tech and Tech Talk to promote specific available times. Currently a brochure is being developed which will be sent to members of the M. I. T. community. The possibility of holding one of the seminars for the Summer Session next year at Talbot House also has been explored.

The problem of financing Talbot House after the Rockefeller grant expires in 1979 has been under review. After evaluating income and expenditures, a new price structure for Talbot House usage has been instituted. We have tried to remain consistent and fair, and thus far, the increases have been well received.

Improvements continue to be made on the house. To comply with the State of Vermont Safety Regulations, a new smoke alarm system which will consist of three smoke detectors and two fire alarms (bells and boxes) with battery back-up is being installed in addition to new fire-proof doors in some of the hallways. The M. I. T. Safety Office has been extremely helpful in making these arrangements.

SUSAN HAIGH HOUPPT

Foreign Study Office

This year the Foreign Study Office was absorbed into the Office of the Dean for Student Affairs, and the Junior Year Abroad and Domestic Year Away programs are being administered on a more limited basis than in the past. Despite this limitation, the Junior Year Abroad library continues to be maintained and updated and interest in these programs is increasing. Since September 1976, there have been approximately 500 student visits to the Dean's Office to inquire about foreign or domestic study. In addition to this number, there have been 110 International Student Identity Cards issued.

Junior Year Abroad

Sixteen students participated in the Junior Year Abroad program during this academic year; ten for the full year, four for the spring term, and two for the summer. The countries in which they studied were England, France (4), Germany (2), Hong Kong, Israel (3), Italy, Norway, Sweden, and the USSR. One student was accepted into the International Honors

Program. At this writing, 11 students already have been accepted into foreign universities for the 1977-78 academic year.

Domestic Year Away

The Domestic Year Away program is an experimental program of the Committee on Educational Policy. In May 1973, the Committee decided to continue the program as an experiment "... pending conclusion of a more general examination of credit, residence and exchange issues." Six students participated in the program; three for the full year at Ohio State University, Stanford University, and Harvard University, two for the spring term at the University of California at Berkeley and the University of Colorado, and one for the summer at Harvard. Although the number of participating students continues to be small, the program greatly benefits many upperclass students whose M.I.T. goals are further defined by having made a thoughtful comparison of M.I.T. study with that at another school.

ROBERT L. HALFMAN

Department of Athletics

The academic year 1976-77 was marked by a period of significant growth and innovation within our athletic program. The growth was mainly in the areas of women's athletics and intramural sports. Of greatest significance was the appointment of three full-time women to the faculty and coaching staff: Professor Jane Betts, Assistant Director, Director of Women's Intercollegiate Athletics and Coach of Women's Gymnastics; Professor Jane Rosenkrans, Coach of Women's Basketball; and Instructor Deborah Clum, Coach of Field Hockey and Women's Softball. The growth in the intramural sports program will be discussed in detail in the section devoted to Intramural Athletics later in this report.

The most successful of the innovations was the merger of the men's and women's intercollegiate squads in two sports, fencing and swimming, for daily practice sessions, thereby enabling maximum utilization of coaching personnel and the facilities available for the two sports. As a result of the merger, the quality of instruction provided for the men and women in both sports has been superior, without the need for a second coaching staff for each sport. The budget implications are obvious, and particularly significant during this period of fiscal constraint in the face of program requirements for increasing numbers of undergraduate women at M.I.T.

Although it has been necessary to extend the hours of daily practices during late afternoons at the swimming pool and the fencing room to accommodate both squads, it was the only way to avoid alternate evening sessions which are most undesirable from the students' point of view.

In addition, the merger has exerted other positive influence within the program, and has generally enhanced many of the values we associate with athletics in the total educational experience at M.I.T. The merger has hastened the acceptance of women in competitive athletics within what has been a dominantly male community. Training in the same facility with the same coaching staff under similar disciplines has fostered a common interest among our men and women in the success of both teams. This has increased their desire to achieve excellence and has greatly enhanced team morale, often in the absence of other spectator interest.

I am pleased to report three items reflecting progress toward the expansion and improvement of our athletic facilities. First, the new Walter C. Wood Sailing Pavilion, dedicated on October 2, 1976, is meeting the expectations projected to maintain the unique role which sailing has played over the years in the lives of so many students, faculty, and staff. Further, a permanent organization known as the "Friends of M.I.T. Sailing" has been organized under the leadership of George Warren Smith, Class of 1926, to provide a continuing relationship between our sailing alumni and the current program.

Second, the firm of Davis, Brody and Associates, Architects, has completed the site plan and schematics for the development of athletic facilities and a major events center to meet the Institute's long-range needs. Also, the final design of Phase I, a new Ice Rink-Field House-Events Center, has been completed and will move into construction upon completion of the current funding campaign.

Third, construction has begun on the Henry G. Steinbrenner Stadium which will provide a new outdoor running track with seating accommodations and a game field for soccer, lacrosse, field hockey, and other outdoor events in addition to track and field competitions. The new facility, including a synthetic surface to meet all weather requirements, will be ready for use in spring, 1978.

Finally, the urgency to complete the funding for the construction of Phase I in the long-range plan for facilities cannot be overstated. This is the major problem facing the Department of Athletics as we strive to maintain a top quality program in athletics and recreation for our students and the M.I.T. community.

PHYSICAL EDUCATION

There were 6,462 registrations in 49 courses offered during the past year, including six courses offered only during Independent Activities Period: Advanced Squash, Basketball Fundamentals, Basketball Officiating, Box Lacrosse, Ice Hockey Skills, and Water Polo.

An analysis of registration statistics for the last five years is shown in Table I. It is interesting to note in parts (b) and (c) a 21 percent increase last year in non-credit registrations and a 72 percent increase over the past five years. This growth reflects a continued popular interest in physical fitness and sports recreation within the M.I.T. family, and further accentuates the need for expanded facilities to accommodate the total program.

Table II portrays registration statistics for 1976-77 by specific courses.

TABLE I

Five-year Summary -- Student and Staff Registrations

	<u>76-77</u>	<u>75-76</u>	<u>74-75</u>	<u>73-74</u>	<u>72-73</u>
(a) Total					
Registration	6,462	6,354	6,882	6,036	5,408
Change Over Previous Year	+108	-528	+846	+628	+503
% Change Over Previous Year	+1.7%	-7.6%	+14%	+11%	+12%
5-Year Change	+19.5%				
<hr/>					
(b) Non-Credit					
Registrations	2,492	2,053	2,653	2,067	1,443
Change Over Previous Year	+439	-614	+586	+624	+108
% Change	+21%	-23%	+28%	+43%	+8%
5-Year Change	+72%				
<hr/>					
(c) Analysis of Non-Credit Registrations					
<u>Students</u>					
1st Year	65	58	63	27	1
2nd Year	308	313	293	171	314
3rd Year	413	282	341	438	229
4th Year	336	388	415	329	270
Graduate	905	734	1,015	713	472
<u>Staff</u>	<u>465</u>	<u>279</u>	<u>526</u>	<u>389</u>	<u>157</u>
	2,492	2,054	2,653	2,067	1,433
<hr/>					
(d) Total Registrations Less Non-Credit Registrations					
Total					
Registrations	6,462	6,354	6,882	6,036	5,408
Non-Credit	<u>-2,492</u>	<u>-2,053</u>	<u>-2,653</u>	<u>-2,067</u>	<u>-1,443</u>
	3,970	4,301	4,229	3,969	3,965

TABLE II

Registration Statistics for 1976-77

Dance	843	Golf	149
Ballet, Beginning	162	Beginning	111
Intermediate	79	Intermediate	38
Folk	94	Pistol	140
Modern Jazz	94	Badminton	125
Partner	308	Sculling	123
Tap	74	Judo	120
Swimming	633	Gymnastics	120
Beginning	302	Beginning	73
Intermediate	79	Trampoline	47
Advanced	60	Touch Football	103
Scuba	60	Softball	91
ARC Life Saving	42	Hatha Yoga	78
ARC Water Safety	50	Rock Climbing	76
Diving	40	Lacrosse	58
Physical Development	480	Karate	54
Tennis	476	Self Defense	38
Beginning	318	Bicycling	24
Intermediate	158	Table Tennis	24
Self Designed Fitness	465	Field Hockey	<u>11</u>
Sailing	357		5,675
Fencing	235	Independent Activities	
Rifle	184	Period	<u>787</u>
Archery	176	Total	<u>6,462</u>
Ice Skating	167		
Beginning	140		
Figure	27		
Squash	165		
Volleyball	160		

INTERCOLLEGIATE ATHLETICS

The deepest commitment to interests in sports participation by M. I. T. undergraduates continues to be made in the area of intercollegiate athletics. Events of the past year have followed the usual pattern: large numbers of students practicing and competing regularly in efforts to achieve excellence -- largely self-motivated, engendering self-respect, pride, and team cohesiveness, winning their share, learning to come back from defeat -- in the absence of major spectator interest. This is amateur athletics at its best!

In response to this depth and quality of student commitment, the Department sponsored varsity and sub-varsity teams in 32 sports, including 10 sports for women which will be reported subsequently in the section on Women's Athletics. Statistically, approximately 915 students competed in 610 events in Cambridge or at New England college or university sites during the past year. Annually, this represents about 20 percent of our undergraduate enrollment, with women participating in about the same proportion.

Peaks and valleys in terms of team and individual performance are characteristic of M. I. T. athletics and the year of 1976-77 was no exception. Outstanding performances included the following:

Frank Richardson, Class of 1977, captain of cross country and track, surpassed all long distance running records in the long history of the two sports at M. I. T. He won the prestigious IC4A Cross Country Championship College Division, and won the NCAA Division III National Championship in the 10,000 meters event.

The cross country team compiled a 26-7 won/lost record over the past three years; indoor track had an 8-1 dual meet season, with outdoor track winning three of its four meets.

Mark Smith, Class of 1978, won the Intercollegiate Fencing Association's foil championship and later led the fencing team to sixth place among all universities in the NCAA National Championships.

Three members of the swimming team won All-America honors at the NCAA Division III Championships.

Letter awards for 1976-77

<u>Undergraduate Men</u>		<u>Undergraduate Women</u>	
Varsity Letters	261	Varsity Letters	70
J-V Letters	157	J-V Letters	31
Frosh Numerals	58	Frosh Numerals	34
	<u>476</u>		<u>135</u>

WOMEN'S ATHLETICS

This year will be recorded as a landmark for women's athletics at M. I. T. Possibly the most significant thing was the hiring of three women faculty members to the Athletic Department faculty. The year was challenging and rewarding as the women's program began to acquire characteristics of stability and to blend into the well-established philosophy of M. I. T. athletics.

Varsity Programs

The women's program included eight varsity sports this past year. Participation statistics by season are as follows:

<u>Fall</u>		<u>Winter</u>		<u>Spring</u>	
Crew	48*	Basketball	15	Crew	22*
Sailing	18*	Fencing	15*	Sailing	18*
Tennis	10	Gymnastics	11	Tennis	10
Volleyball	12*	Swimming	21		

The volleyball team was undefeated in 21 regular season matches, winning the Championships of the Metropolitan Women's Intercollegiate Athletic Council (MWIAC) and the Massachusetts Association for Intercollegiate Athletics for Women (MAIAW). In post-season play, they won the Eastern Regional AIAW Tournament, and competed in the AIAW National Championships for small colleges at Malibu, California.

Judy Austin, Class of 1977, led the fencing team to a ten and seven record. She placed third in the New England Women's Fencing Championships and competed in the Women's Intercollegiate Fencing Association's National Championships.

Club Programs

Five teams functioned at the club level during the 1976-77 year. Softball was the only club having participation in prior years. Cross country, field hockey, rugby, and water polo each filed letters with the M. I. T. A. A. Executive Committee requesting recognition as M. I. T. A. A. club sports. At the conclusion of the field hockey season and the softball season, representatives from these sports applied to the M. I. T. A. A. Executive Committee for varsity status. The request was approved by the M. I. T. A. A. and the Athletic Board.

Club sports participation included: cross country 6, field hockey 12, rugby 16, softball 13, water polo 11.

Special Activities

A brochure devoted to women's athletics at M. I. T. was designed and printed during this year. The brochure was disseminated to prospective students through the Athletic Department, used by the Office of Admissions, and distributed to Educational Counselors.

In the fall, all undergraduate women were sent a questionnaire soliciting their interest in intramural activities, participation and desire for change. The results were informative and have been given to the chairman of the Intramural Council for consideration in planning the 1977-78 program. The 1977 Intramural Softball Program included, for the first time, a separate league for women.

The status of athletic awards for women was reviewed by a committee of coaches of women's sports. The realistic probability of women receiving the Kispert, Cochrane, and Class of 1948 Awards was discussed and recommendations for two new awards for women were made to the Athletic Director.

* includes sub-varsity teams in regular competition

The Women's Athletic Council was the recipient of a Stewart Award at the Annual M. I. T. Awards Convocation. Caren Penso was selected by the Women's Athletic Council to receive the M. I. T. A. A. Pewter Bowl, and Barbara Belt was selected to receive the Betsy Schumacker Award.

On October 9 and 10, M. I. T. hosted the Metropolitan Women's Intercollegiate Athletic Council (M. W. I. A. C.) Annual Tennis Tournament in which nine member schools participated.

On October 29 and 30, M. I. T. conducted a coaches clinic featuring 1976 Women's Olympic Basketball Coach Billie Moore. The event was attended by 115 coaches of women's basketball.

M. I. T. hosted the M. W. I. A. C. Swim Championship on February 12. This annual meet was attended by seven member institutions.

A search was conducted in the spring for a candidate for the new position of Athletic Trainer/Instructor of Physical Education. Fifty-four applicants were considered and four final candidates interviewed. Once the Selection Committee made the final decision, the position was offered to and accepted by Harriet Pearce.

Improving the visibility and stability of the M. I. T. Women's Athletic Program was the major target of the Director of Women's Athletics this year. The staff members and students involved in the women's program contributed to the attainment of these goals.

Visibility was promoted within the community by discussing the program at a women's faculty luncheon, a women's graduate student meeting, a wives of foreign students meeting, and a women's advisory group meeting; through the Athletic Department/Admissions Office liaison; and at the Alumni All Sports Night. A large display of women's athletics activities was provided for a High School Careers Day for Women sponsored by the Admissions Office and the Association of Women Students.

Regionally and nationally, the success of the volleyball team brought recognition to M. I. T. It is hoped that attendance at and involvement in regional and national professional meetings have contributed to the visibility of M. I. T. Women's Athletics.

With 10 varsity sports, a large percentage of full-time coaches, and an athletic trainer, the women's program promises to set roots that will grow, meeting the current and future needs of students. The Women's Athletic Council is defining and accepting projects related to prospective student contacts and alumnae relations. This group is moving in a positive direction that should enhance the overall stability of the program.

INTRAMURAL ATHLETICS

Intramural sports regularly attract more than two-thirds of our undergraduate men and women and a significant number of graduate students and young faculty members. The total growth of the program consisting of 23 sports was 4.6 percent for the past year. Hopefully, the growth is leveling off after a three-year surge where increases of 10, 11, and 29 percent were experienced beginning with the academic year 1973-74. During this period the number of basketball teams increased from 108 to 143, volleyball 82 to 128, soccer 42 to 58.

The crunch on indoor facilities to accommodate this growth has resulted in a serious dilution of the participation experience of the many students who, for various reasons, elect the less formal commitment associated with intramural athletics. Suggestions such as a lottery

system to reduce the number of teams to enable greater participation for reduced numbers have been rejected thus far by student choice. In ice hockey, for example, where the capabilities of the existing outdoor rink have been exhausted for years, the student organized Intramural Council has been renting ice time at nearby rinks operated by the Metropolitan District Commission. The primary need of the intramural athletic program, as well as for the total program, continues to be construction of the facilities planned within the new Ice Rink-Field House-Events Center.

Intramural Participation Statistics for 1976-77

<u>Sport</u>	<u>No. of Teams</u>	<u>Total Participants</u>
Badminton	46	184
Basketball	145	1,160
Bowling	121	363
Chess	20	120
Cross Country	17	113
Cycling	11	53
Football	75	1,125
Hockey	62	620
Indoor Track	13	84
Pool	21	105
Rifle	35	148
Sailing	8	32
Soccer	58	1,044
Softball	148	1,924
Squash	45	180
Swimming	21	112
Table Tennis	42	294
Tennis	77	385
Track	13	108
Volleyball	128	1,024
Water Polo	36	360
Weight Lifting	7	36
Wrestling	14	108
	<u>1,163</u>	<u>9,682</u>

Club Athletics

Club athletics serve a very real need among special interest groups within the M. I. T. community, particularly in sports and recreational activities in which there is no formally organized counterpart elsewhere in the program. Also, since club teams are not subject to the eligibility rules associated with the intercollegiate varsity program, they have great appeal among graduate students and young members of the teaching staff, i. e. graduate crew and soccer.

Clubs Active in 1976-77

Archery	12	Karate (2 clubs)	35
Badminton	14	Rifle/Pistol	47
Bicycling	10	Rugby (2 clubs)	32
Graduate Crew	12	Scuba	35
Cricket	18	Graduate Soccer	18
Dance Workshop	14	Squash (Women's)	12
Folk Dance	20	Table Tennis	12
Round Dance	30	Trampoline	8
Fencing	15	Volleyball (Men's)	12
Figure Skating	10	Water Polo	14
Frisbee	15	Weight Lifting	10
Judo	17	White Water	18

Recreation for Students and the M.I.T. Community

One of the major objectives within the M.I.T. athletic program is to introduce students and staff to sports interests which may be developed into life-long recreational outlets. Toward the attainment of this goal, the Department offers sports instruction through a variety of courses in the physical education curriculum, shore school at the Sailing Pavilion, sculling instruction at the crew house, summer tennis classes, and swimming and ice skating classes for faculty/staff children. Family swim night on Friday evenings is extremely popular. This past spring we were able to light a section of the du Pont Tennis courts through a gift from Harold Brown, Class of 1947. Mr. Brown's generosity will enable us to extend significantly the use of six of our 21 tennis courts.

The annual sale of Athletic Cards is the best single index to the recreational use made of the Institute's athletic facilities. This past year, a total of 8,928 Cards were purchased within the M.I.T. community, including 6,537 by undergraduate and graduate students, which represents 77 percent of the full-time registered students during the year.

Athletic Card Sales for 1976-77

Students		6,537
Faculty	395	
Academic Staff	1,088	
Exempt Employees	45	
Bi-Weekly Employees	360	
Weekly	<u>110</u>	1,998
Alumni		<u>393</u>
		8,928
Sailing Cards:		
Students	697	
Faculty/Staff	148	
Alumni	74	
Specials	168	
Physical Education	<u>357</u>	1,444

Cambridge and Greater Boston Community Relations

The Department continues to work closely with the office of Walter Milne, Special Assistant to the President for Urban Affairs, in the extension of the M. I. T. facilities to community interests at times not in conflict with our primary commitment to M. I. T. students.

Students are encouraged to sponsor Cambridge youth on a one student-one guest basis during open hours at the swimming pool and ice rink. Special programs for larger groups are accommodated during recess periods, including an annual Cambridge Mayor's reception during the spring recess. New events this past year included swimming instruction for toddlers sponsored by the M. I. T. Child Day Care Center. Also, the playing fields and indoor facilities were extended to the Cambridge Latin and Rindge Tech schools for physical education classes and interscholastics during the reconstruction program under way at both schools.

Major Athletic Awards for 1976-77

The Class of 1948 Award to the Senior Athlete of the Year was presented to Frank C. Richardson, Class of 1977. The Admiral Edward L. Cochrane Award to the Senior who has best combined the qualities of leadership, humility and scholarship in intercollegiate athletics was presented to John A. Cavolowsky, Class of 1977.

Frank C. Richardson, Class of 1977, received the Malcolm G. Kispert Award to the senior scholar-athlete of the year. The Betsy Schumacker Award for excellence in athletic competition by a woman student went to Barbara A. Belt, Class of 1977. Caren T. Penso, Class of 1977, received the M. I. T. A. A. Pewter Bowl for outstanding contributions to women's athletics by a woman student. The Straight T. Award for national or regional recognition in intercollegiate athletics at M. I. T. was presented to Celia A. Berry, Class of 1978 and Jeffrey P. Singer, Class of 1977. Glenn R. Brownstein, Class of 1977, won the Burton R. Anderson, Jr., Award to the Manager of the Year.

The Varsity Club Award to the Frosh Athlete of the Year was presented to John M. Dieken, Class of 1980. The Harold J. Pettegrove Award for outstanding contributions to intramural athletics went to Edward M. Cluss, Class of 1977.

Staff Changes During 1976-77

Jane Betts was appointed Associate Professor in Physical Education, Assistant Director of Athletics, and Coach of Women's Gymnastics. Jane Rosenkrans was appointed Assistant Professor in Physical Education and Coach of Women's Basketball. Deborah Clum was appointed Instructor in Physical Education and Coach of Women's Field Hockey and Softball. Bruce Keeshin was appointed Instructor in Physical Education and Coach of Men's Gymnastics. The above appointments were effective July 1, 1976. Pasquale E. Melaragno was appointed Instructor in Physical Education, Rangemaster, and Coach of Pistol, effective January 1, 1977.

Jill A. Gilpatric was promoted from Secretary to Sports Information Director effective September 1, 1976. Stuart A. Nelson, Instructor in Physical Education, Assistant Sailing Master, and Coach of Women's Sailing was promoted from Exempt to Academic Staff, effective September 1, 1976.

Peter M. Close, Instructor in Physical Education, Head Coach of Cross Country, and Assistant Coach of Track resigned effective June 30, 1977, to accept the position of Head Coach of Track and Cross Country at Tufts University. Jane Rosenkrans, Assistant Professor in

Dean for Student Affairs

Physical Education and Coach of Women's Basketball resigned effective June 30, 1977, to accept the position of Instructor in Physical Education and Coach of Women's Basketball at Springfield College.

Thomas P. McLennan, Instructor in Physical Education, Rangemaster, and Coach of Pistol died on September 1, 1976.

ROSS H. SMITH

Provost

The Report of the President and the Chancellor focuses among other topics upon evolving academic forms, developments whose impact on the activities of the Provost's office has been profound. The emergence of a novel academic unit -- a so-called "college" -- requires a major effort in order to understand how such a unit might fit and successfully function in the present day ecology of academic entities at M.I.T. It would be presumptuous to assume that the initial conceptualization of a unit as complex as an M.I.T. college will remain unchanged in the years to come. If there are to be several such colleges they are likely to differ with respect to both history and evolution. Most profoundly they will differ because they aim at a form of academic synthesis in different realms of knowledge and action. Hence each such college will be -- like M.I.T.'s departments, Schools, laboratories, centers, and programs -- sui generis. And yet there will need to be sufficient similarity between such units if the term "college" is to come to have a significant meaning.

Over the years, and especially since World War II, M.I.T. has, as an institution, pioneered in the evolution of academic organization. The Institute has recognized that disciplines, professions, missions, and societal needs change and these changes have often been reflected in the names of departments and laboratories. The Institute has been both responsibly experimental and sufficiently critical in its academic organization to try to adapt itself to new realities.

One of the ways in which M.I.T. has adapted is in the formation of multiinstitutional consortia whenever the acquisition of special facilities or the complementarity of academic resources required such arrangements. During the past several years members of the M.I.T. faculty and colleagues of eight other Boston area cultural and educational institutions -- with the administrative assistance and leadership of Joel Orlen -- have worked to establish a Center for Materials Research in Archaeology and Ethnology. As the academic year 1976-77 comes to an end we report with pleasure that the culmination of this significant effort is in sight. We hope to be able to assess next year more fully this unique development.

Since 1971, the Technology and Culture Seminar at M.I.T. has been a forum for the discussion of a range of broad issues -- ethical, social, political, economic, epistemological -- raised by the impact of modern science and technology on society and culture.

The Technology and Culture Seminar had the support of a loyal and broadly representative group of faculty, and was conducted under the guidance of a faculty steering committee consisting of Professors Robert L. Bishop, Elting E. Morison, Robert S. Morison, Leon Trilling, and Victor F. Weisskopf; Associate Professors Jonathan A. King, Stephen D. Senturia, and Judith Wechsler; and Mr. Orlen, Executive Officer of the Provost's office, representing the Provost. The Reverend John Crocker served as chairman of the steering committee and convener of the Seminar, and was in many ways the moving spirit of this effort. Reverend Crocker was Episcopal Chaplain at M.I.T. until he left this summer to become rector of Trinity Church in Princeton, New Jersey. His absence will be strongly felt.

The Seminar focused its primary attention on issues of concern to the faculty, which were discussed in small luncheon groups that met every other week for one term or for an entire academic year. Many of the Seminar's activities were open to the entire M.I.T. community.

Provost

Most prominent among these were a variety of widely-publicized, public-lecture series held usually in the 9-150 lecture hall. The public lecture series for the current year took place during the spring term. It was entitled Darwinism and Culture, and it was organized jointly by Professor Alvin C. Kibel of the Department of Humanities and Professor Stanford Anderson of the Department of Architecture, as an adjunct to an M.I.T. academic subject also entitled Darwinism and Culture, which the two professors taught as a team. The lecture series included the following speakers: Everett Mendelsohn, Harvard University; John C. Greene, University of Connecticut; Richard C. Lewontin, Harvard University; George W. Stocking, Jr., University of Chicago; Jared M. Diamond, UCLA; Marjorie Grene, University of California at Davis.

The need for the discussion of the issues that were of central concern to the Seminar will clearly persist even though the modus operandi of the forum may change somewhat in the context of other developments.

During the past several years M.I.T. faculty members have become increasingly involved in a variety of undertakings that are somewhat imprecisely grouped under the catch phrase of "international programs." These programs range from those that bring groups of students for certain educational programs to the Institute (some of them come under the auspices of certain modest exchange agreements) to others in which technical assistance (from technology transfer to institution-building) is extended to developing countries under the sponsorship of the Agency for International Development. In still other projects research in areas of common interest is being undertaken in which M.I.T. faculty members collaborate with professional colleagues in other countries.

As these efforts have gained in scale and scope, the M.I.T. faculty have explored their manifold implications in several ad hoc committees. During this past year the M.I.T. faculty has established a continuing Committee on International Institutional Commitments (C.I.I.C.) which provides policy guidance to faculty members and the administration. The Provost welcomes this development since he is only too much aware that some of the most technically and scientifically challenging projects call for novel arrangements demanding careful scrutiny from a variety of perspectives not necessary when research proposals for domestic sponsors are prepared. Altogether the time has come to examine in depth the role of M.I.T. as a unique national and international educational, research, and service institution.

WALTER A. ROSENBLITH

American Journal of Physics

In 1973 the Institute became the home of the American Journal of Physics, a journal "devoted to the instructional and cultural aspects of physical science," sponsored by the American Association of Physics Teachers. Dr. Edwin F. Taylor, Senior Research Scientist in the Department of Physics and the Division for Study and Research in Education, is Editor. Professor Anthony P. French is Consulting Editor, Dr. Steven Berger, an M.I.T. Ph.D., is Assistant Editor, and Carol Frakes and K. Toni Ramos assist in the editorial office.

Artificial Intelligence Laboratory

The American Journal of Physics, published 12 times a year, is the foremost publication in physics education at the college and university level. Typical contributions deal with new ways of visualizing and teaching traditional physics subjects; discussions of specialized topics of particular interest or importance; new ways of organizing courses in physics; novel experiments and apparatus; the uses of computers, films, and other aids in teaching; and historical articles about fundamental developments and personalities in science.

EDWIN F. TAYLOR

Artificial Intelligence Laboratory

The primary goal of the Artificial Intelligence Laboratory is to understand how computers can be made to exhibit intelligence. Two corollary goals are to make computers more useful and to understand certain aspects of human intelligence. The research program includes work on computer vision and manipulation, intelligent personal assistants, English language understanding, learning and automatic debugging, common sense reasoning, expert engineering problem solving, manufacturing productivity, computer architecture, human development, and human education.

Professor Patrick H. Winston is responsible for the general direction of the laboratory. This year, Professors Marvin Minsky and Seymour Papert worked on the development of general theories of artificial and natural intelligence. Professor Berthold K. P. Horn and Dr. David Marr led work on computer vision. Professor Horn also supervised work on computer controlled, multiple-joint manipulators and other problems in manufacturing productivity. Professor Ira Goldstein directed research on automatic news analysis, common-sense resource scheduling, and user-sensitive computer interfaces. Professor Gerald Sussman worked on programs that reason about electronic circuits. Professor Carl Hewitt investigated new programming models and developed the ACTOR language. Professor Vaughan Pratt worked on LINGOL, a syntactic English parser. Professors Jeanne Bamberger, Andrea diSessa, and Harold Abelson worked with Professor Papert to develop uses of technology in education and to construct corollary cognitive theories. Richard Greenblatt and Thomas Knight led work on computer systems including the development of a high-performance processor oriented toward the symbol manipulation required by intelligent programs.

A total of 10 faculty, seven visitors, one research associate, one lecturer, 11 research staff, seven support staff, 45 graduate students, and 20 undergraduate students were involved in research activities which were funded during fiscal year 1977 by the Defense Advanced Research Projects Agency, the National Science Foundation, the National Institute of Education, the International Business Machines Corporation, and the National Aeronautics and Space Administration.

Image Understanding

Professor Horn's group has spent considerable time working on the automatic understanding of aerial photographs. In particular, Professor Horn has devised a representation called the reflectance map to describe how reflected intensity is controlled by surface material, surface orientation, and light-source position. Reflectance maps enable the generation of synthetic high-altitude images from terrain models. Correlating a real image with a synthetic one can establish the proper registration of the real image with a terrain model in preparation

for various sorts of automated cartography and improved crop forecasting. To keep computational time within reasonable bounds, Professor Horn correlates reduced real and synthetic images in translation, rotation, and scale space to give approximate registration. Then the process is repeated with high resolution images to achieve high accuracy. The method potentially yields registration accuracy in the subpixel range.

Professor Horn has just begun another project that involves making shaded maps using two or more imaginary suns distributed at key points around the sky. Such maps give a faster, better appreciation of the terrain than ordinary shaded maps. Formally, the reason is that the intensity of a point in an ordinary black and white image is not sufficient to determine the surface normal at that point. There is constraint, however, and one black and white intensity does limit the normal to lie on a definite iso-intensity curve in the reflectance map. Using multiple suns, each of a different color in a different part of the sky, two or more separate curves in reflectance-map space are obtained. Their intersection gives the surface normal unambiguously.

During the last year Professor Horn also has studied color reproduction, and he has derived criteria that ensure reproduction accuracy. The central theorem is that the image sensors must have response curves that are linear transformations of those in the human retina. This demonstrates that the recent images sent from Mars cannot be used to create a faithful color photograph. The spectra of a reproduction system's light-producing phosphors or light-absorbing dyes are not so constrained, however, and Professor Horn has shown how to match sensor outputs to phosphors or dyes by inserting linear transforms between them.

Dr. Marr's group continued to work on vision from a complementary perspective. Believing that an overall theory of vision must rely on explicit descriptions at the right levels, he has concentrated on three representations: the primal sketch for information about the position, orientation, length, contrast, and type of each edge fragment observed; the 2 1/2 D sketch for information about surface orientation, depth, and contours of depth discontinuity; and finally, the generalized cone data base for information about shapes of objects in terms of 3 D curves and 2 D shapes projected along them. Each of these representations was devised to make some particular kind of information explicit. Each in turn helps to define the computational problems that eventually lead to working algorithms.

The information in the primal sketch seems to have a major role in determining texture. Bruce Schatz found evidence indicating that texture is determined by first order statistics on a subset of the primal sketch descriptors. It seems that only ungrouped edge fragments and virtual lines connecting neighboring edge points are needed. Moreover, it seems that the analysis of these texture-determining descriptors can be quite coarse. Mike Riley has shown that histograms of line orientation with only five or six buckets seem sufficient for handling the line-orientation part of texture discrimination with human-level competence. Related experiments seem to show that intensity histograms can be quite coarse as well, although work in this direction is preliminary.

At the generalized-cone level of representation, Dr. Marr and Keith Nishihara have worked out means by which hierarchies of generalized-cone descriptions can be assembled together using body-centered coordinate systems. One seemingly important theorem discovered by Dr. Marr states that if a surface is part of a generalized cone, then the points on the surface that correspond to the observed boundary all lie in a plane.

Intelligent Personal Assistant Systems

Professor Goldstein's group has concentrated on programs that exhibit and deliver common-sense knowledge. The overall objective is a system that begins with an input module that accepts information in English, then performs some task such as planning and scheduling

an expenditure of resources, and finally communicates what has happened back to the user in an explanation specifically tailored to the user's needs.

Much of this work is based on frame technology. Professor Goldstein's group has implemented a frame language, FRL, in which a frame has the following components: slots and attributes of slots such as values, default values, expectations, and restrictions; demon-like procedures that are activated when slot values are asserted, removed, or requested; and inheritance links that allow the slot attributes of one frame to be obtained from another.

During the past year, a frame-based program for coaching users in playing a simple game led to substantial improvement in user modeling and model-based explanation. The coach features a theory of overlays for modeling and a thematic grammar for trimming formal logical proofs to their critical core.

Other progress was made in natural language understanding with the development of ideas for tying pronouns and paraphrases to their antecedents and with the completion of a new syntactic analyzer. Unlike older analyzers, the new one takes time in linear proportion to sentence length -- there is no backup to cause exponential search. The program's structure consists of a push-down stack and a set of situation-action rules that monitor and modify three registers containing words and intermediate sentence constituents. All words flow through these three registers as analysis proceeds.

Expert Problem Solving

Professor Sussman and his group have been building a problem solver for electrical design that learns from its own mistakes. The problem solver's design is strongly influenced by the belief that the creation and removal of "bugs" is an unavoidable part of the process of solving complex problems. The process of localization and removal of bugs requires an approach to engineering analysis in which every result has a justification that describes the exact set of assumptions it depends on. Programs written in accordance with this approach analyze circuits in a way that allows explanation of the deductions made. These explanations are useful to a cooperating human designer as well as to the automatic analysis procedures.

Basic Theory

Professors Minsky and Papert are developing a theory of intelligence that combines elements from developmental, psychoanalytic, and cognitive theories with ideas from Artificial Intelligence. In this society theory, the intelligence emerges from the interaction of large "societies" of rather simple individual "agents," in a parallel computational structure. Because each agent is relatively simple, communication between agents must be very restricted, both in amount and in complexity of information.

The approach may illuminate some long-standing mysteries such as the conservation phenomena explored by Piaget and the ego-formation phenomena studied by Freud. The limitations of inter-agent communication make it necessary for the mind to develop hierarchies of control structures that we may be able to identify with developmental stages, and members of these hierarchies must settle conflicts by using critics, censors, and references to early-developed self-images.

Whether or not these psychological aspects of the theory become fruitful, the work suggests new ways to organize very large knowledge based computer programs and, perhaps, some ideas about building large, active computer memories.

In another study, Professor Winston devised a program that understands how to decipher simple metaphors such as "The Forrestal is like a mountain." The frames representation was used because it makes the problem one of finding the right frame slot and the right value to put into it. This can be hard, particularly for metaphors that have not yet become part of the culture. Professor Winston's program uses context, knowledge about what the teacher knows, and knowledge about what the student wants to know to make its decisions.

Manufacturing Productivity

To advance the state of the art in automation, Professor Horn is doing long-term research in computer vision, computer controlled manipulation, and high-level programming languages.

Manipulator control was the prime focus during the last year. Professor Horn solved the intricate problem of calculating the forces needed to move a six-joint arm along a prescribed trajectory using an Euler-Lagrange approach, but the resulting formulas are much too large to use in real-time control. One alternative is to relate joint torques to accelerations using a large, 12-dimensional table indexed on joint angles and joint velocities. With such a table, just getting the entries can be difficult, however. Professor Horn supervised work on the problem in cooperation with Professor Whitman Richards of the Department of Psychology. This work led to manipulator control programs that improve themselves by learning table values through careful analysis of practice movements. Currently Professor Horn is working on a new theory that combines table look-up with some real-time computation. The method promises to reduce the dimensionality of the necessary table from 12 to six, thereby dramatically reducing the storage needed.

Computer Systems Development

Intelligent information processing places unusual demands on computers. Consequently, Richard Greenblatt, Thomas Knight, and their colleagues have designed a new computer that gives its users more symbol-manipulation and list-processing power than ever available before. Through careful design and full exploitation of the latest integrated circuits, this new computer performs much better and costs much less than the best usable commercial computers. Work on software has progressed very rapidly in the past year and large programs have been demonstrated. One such program is the MACSYMA system for applied mathematics developed in the Laboratory for Computer Science. Another is a large natural-language-understanding system designed for data base access. The processor's features include hardware data types, interleaved processing and garbage collection, a very large address space, and a very general microcode that enables, among other things, a uniquely powerful function-calling instruction.

Education

Professor Papert's education group is dedicated to learning how students can develop their own problem-solving procedures using computer programs as models. Experimental work was greatly facilitated during the year by the new Learning Laboratory, and other support was made possible by the Division for Study and Research in Education. About 15 fifth-grade children used this new facility last year. Results have been encouraging -- participating students have increased their language skills, their understanding of the thinking process, and their mathematical competence. Professors Abelson and diSessa also used Learning Laboratory's equipment in teaching differential geometry, orbital mechanics, and other subjects to 15

high-school students during a National Science Foundation sponsored summer program. This work was part of an effort to reconceptualize traditional subject areas.

PATRICK H. WINSTON

Center for Advanced Visual Studies (C.A.V.S.)

The Center for Advanced Visual Studies, in this past 10th year of its operation, realized a major collaborative project, "Centerbeam," involving the C.A.V.S. director, Fellows, and staff. "Centerbeam" was designed as the C.A.V.S. contribution to documenta 6, a quadrennial international art exhibition held in Kassel, Germany from June 24 through October 2, 1977. Execution of the environmental, kinetic sculpture demanded extensive design, planning and fund-raising efforts, and C.A.V.S. was helped by senior M.I.T. officers, and several departments.

"Centerbeam" combines art, science, and engineering in a unique way. It is composed of numerous elements including video, laser scanned projections, holograms, processed sounds, neon/argon, ice, a steam screen/cloud, poems, and botanical growth. Daylight, solar-tracked holograms are incorporated into the piece and are being exhibited for the first time. The elements are organized as a network of energy and communication lines extending along a 144-foot long water trough that serves as an immense prism catching and reflecting the sun's rays. The elements interact with each other, the landscape, and spectators, producing dramatic displays.

The work has many features that invite the viewer to participate, such as manipulable holograms and mirrors, interactive video, and processed sounds activated by the viewer's presence, movement, and voice. At a distance the work becomes a monumental display of sounds, lights, and spectral effects. "Centerbeam" also illustrates the sculptural possibilities for energy generated by wind, sun, and photosynthesis. The concept for "Centerbeam" was originated by Fellow Lowry Burgess. Professor Otto Piene directed all project efforts, and Elizabeth Goldring was the project coordinator.

In addition to documenta 6 sponsorship, the project has received generous support from the President's Office, the United States Information Agency, the International Telephone and Telegraph Corporation, and the Alcoa Foundation.

For the academic year 1976-77, C.A.V.S. received for the first time a substantial financial contribution from the Department of Architecture, in acknowledgement of the continued and expanded teaching efforts by C.A.V.S. staff members. During the academic year, 10 subjects offered by C.A.V.S. staff members attracted 193 students from M.I.T., Harvard University Wellesley College, and Massachusetts College of Art. Derith Glover and Michael Moser were the first to obtain Master of Science degrees in the area of Visual Studies.

Augmenting M.I.T. contributions to the Center's budget, C.A.V.S. received financial support from a number of sources. A Sloan Foundation Grant supported the course, "Image Processing and Manipulation," a video and experimental TV course which will continue to be offered in conjunction with the Center for Advanced Engineering Study. Other funds made possible the following projects: "50 Photos from the Best of Life" by Antonio Muntadas (The Sumner Foundation for the Arts); "A Grimm Duo," two chamber operas based on fairy tales by Paul Earls (New England Chamber Opera Group Trust and the M.I.T. Council for the Arts); and

a workshop program for C. A. V. S. Fellows (National Endowment for the Arts, Visual Arts Program). The Rockefeller Foundation continued support for Fellow Ron Hays. Bradley C. Higgins of the Electric Boiler Corporation of America allocated a grant to Joan Brigham for a dance piece in steam, yet to be realized. Additional contributions include the above-mentioned support for "Centerbeam."

During the past year the Center's exhibition space was utilized in several different ways. Exhibitions included John Newman's "Double Articulation," a group of wall reliefs designed specifically for the space, and Carl Nesjar's "Mud and Ice Photographs," a collection taken during his installation of a Picasso sculpture in Rolling Meadows, Illinois. Other events scheduled in the exhibition room were the performance of Paul Earls' "Doppelganger" for oboes and laser and a screening of Jon Rubin's experimental films. After the Paik-Abe video synthesizer was installed at C.A.V.S., Nam June Paik visited the Center and showed a selection of his videotapes. The synthesizer, formerly housed at the WGBH-TV workshop, was brought to C. A. V. S. by Ron Hays and installed by Mark Chow, both Fellows at the Center.

C.A.V.S. director Otto Piene's professional activities in the past year included: "Anemones, An Air Aquarium," an indoor environment of inflatables for Creative Time, Inc. in New York City; a sky event, "Black Stack Helium Sculpture" for "The River: Images of the Mississippi," Walker Art Center, Minneapolis, Minnesota; a sky event, "Lakefront Anemone," for the Lakefront Festival of the Milwaukee Art Center; an exhibition of his paintings at the Fitchburg Art Museum, Fitchburg, Massachusetts; and another one-man show at the Galerie Schoeller in Dusseldorf, Germany. He visited Princeton University as a guest lecturer and artist of the Princeton Humanities Council and staged his "Princeton Sky Event" over the Princeton Cannon Green. A large volume, "Werkverzeichnis," a biography and catalogue raisonné of his graphic work, with text contributions by Gyorgy Kepes, Lawrence Alloway, Juliane Roh, Wulf Herzogenrath and others, was published by Edition Rottloff in Karlsruhe, Germany.

Gyorgy Kepes, Institute Professor Emeritus and C.A.V.S. director emeritus, had exhibitions abroad at the Künstlerhaus in Vienna and at the Bauhaus Archive Museum in Berlin. His photographs were exhibited at Prakash Gallery, New York City and Wirtz Gallery, San Francisco. Locally, Visions Gallery in Boston hosted a show of his photographs, which ran concurrently with an exhibition of his paintings at Alpha Gallery. Exhibitions of his work are scheduled for this fall at Robinson Gallery, Houston, Texas; Hopkins Center, Dartmouth College; and the Fitchburg Art Museum.

The diverse and numerous activities of C. A. V. S. Fellows became manifest in exhibitions and projects outside the Center as well. Independent of the C. A. V. S. "Centerbeam" project, individual contributions to documenta 6 were made by Fellows Peter Campus, Antonio Muntadas, Alan Sonfist, and former Fellow, Vassilakis Takis. Hayden Gallery presented "Mask Projections," video installations by Peter Campus. His video work also had one-person showings at the Museum of Modern Art in New York City and at Ohio State University, Columbus. "Video Works '71-77" and "The Animal Series" by Antonio Muntadas were screened at the Everson Museum of Art in Syracuse, New York. A video/performance piece by Aldo Tambellini was part of the Centerscreen Visiting Artist Series at Harvard University. He also realized the first two-way live picture-phone event by artists, with Sonia Sheridan, at Illinois Bell Telephone in Chicago. Mr. Hays served as visual designer and consultant on various films, theatrical events, and video productions, including "Demon Seed" for Metro Goldwyn Mayer and "The Lily Tomlin Special," a nationwide public television broadcast. He also directed a multi-media experience at the New Orleans Superdome.

C.A.V.S. Fellows made significant contributions to the art environment in the Boston area. Paul Earls acted as artistic director and provided music and laser work for "Dreamstage: A Multi-Media Portrait of the Sleeping Brain" at Harvard University's Carpenter Center for the

Visual Arts. The exhibition received major news coverage, and attendance exceeded 10,000 people. Alejandro Sina had his first one-man exhibition, "Gaslight Phenomenon," at the Institute of Contemporary Art in Boston. He installed a large-scale argon-mercury sculpture in the new Hyatt Regency Hotel in Cambridge. Lincoln Laboratory in Lexington hosted a show of drawings by Ms. Brigham. Her steam event, "Under Aquarius," a multi-media collaboration with former Fellow Stan VanDerBeek, saw a repeat performance at Hampshire College in Amherst.

During the past year Fellows of the Center were involved in a variety of local innovative projects. Virginia Gunter was the first artist to participate in a new artist-in-residency program at the Boston Museum of Science. Cosponsored by the Boston Visual Artists Union, it provides artists with working space within the Museum and offers visitors the chance to see and talk with the artist at work. Mr. Rubin helped to found the Boston Film/Video Foundation, Inc., conceived as a regional media center to encourage independent film and video work. His own films were screened as part of a series showing the work of experimental filmmakers at the Institute of Contemporary Art.

Fellows and staff members of C.A.V.S. participated in "First Night," the city's New Year's Eve celebration on Boston Common; the first Cambridge River Festival; and the Quality of Life Competition sponsored by the Cambridge Arts Council. Fellow Mark Mendel received first prize in the competition for his proposal of an environmental poem for a Cambridge wall. Both John Newman and Alan Sonfist had one-person shows in New York City, and Harriet Casdin-Silver was chosen as the first one-person exhibitor at the New York Museum of Holography, following her participation in its opening exhibition early in 1977. The work of sculptor Michio Ihara received a one-person showing at Staempfli Gallery in New York City.

Elsewhere, the New Orleans Museum of Art sponsored a major exhibition of work by Grover Mouton. "New Orleans at Zero Gravity" is the artist's reconsideration of an existing urban technology within the bounds of zero gravity metaphors. One-person exhibitions of Friedrich St. Florian's work were held at the University Art Museum, The University of Texas in Austin, and at the Museum of Art, Rhode Island School of Design (RISD) in Providence. He also helped to organize two major symposia, "The European Management Forum" in Davos, Switzerland and "Positions in Architecture Z" at RISD. Karin Bacon coordinated "Festival Tour Events -- 1977," a nationwide program of regional festivals, for the National Endowment for the Arts. Mr. Mendel served a 12-week residency as Visiting Poet in two elementary schools in Columbus, Georgia. The program was sponsored by the Georgia Arts Council and resulted in the creation of an outdoor urban anthology of children's poems. He also taught stonemasonry at Paolo Soleri's Arizona city, Arcosanti. Mr. Rubin staged film screenings in New York, Chicago, Houston, San Francisco, and Vancouver.

Commissions for work were given to Mr. Ihara for architectural sculptures for the Hyatt Regency Hotel in New Orleans; the Springfield Riverfront Park in Springfield, Massachusetts; and the Downtown Square of the City of Auckland, New Zealand. Mr. Nesjar is working on a commissioned fountain and park project in Moss, Norway, scheduled for completion in fall, 1977.

Reviews of work by C.A.V.S. Fellows appeared in prominent art journals, including: "About Faces: the New Work of Peter Campus" by Roberta Smith in Art in America and a review of his video work by Steven Madoff in Artforum.

Among significant honors awarded to C.A.V.S. Fellows during the past year was Mr. Rubin's Guggenheim Fellowship. Mr. St. Florian was appointed Chairman of the School of Architectural Studies at RISD, while Ms. Brigham was granted tenure as Assistant Professor of Fine Arts at Emerson College in Boston.

In the Master of Science program in Visual Studies, Derith Glover developed, together with Richard Warner of the Charles Stark Draper Laboratory, an optical drawing system as her thesis project. Graduate student Chris Janney's "Sound Stair" in Staircase 7 generated acclaim and debate. Mike Moser, right after finishing his video Master of Science thesis work, became a major video participant in the "Centerbeam" project.

In 1976-77 the following artists were appointed Fellows at the Center for Advanced Visual Studies: Karin Bacon, Joan Brigham, Lowry Burgess, Peter Campus, Harriet Casdin-Silver, Mark Chow, Dan Dailey, Paul Earls, Elizabeth Goldring, Virginia Gunter, Ron Hays, Michio Ihara, Mark Mendel, Grover Mouton, Antonio Muntadas, Carl Nesjar, John Newman, Jon Rubin, Friedrich St. Florian, Alan Sonfist, Alejandro Sina, and Aldo Tambellini.

The fall of 1977 will mark the tenth anniversary of the Center for Advanced Visual Studies.

OTTO PIENE

Cell Culture Center

The Cell Culture Center at M.I.T. has been established and funded by the Human Cell Biology Program of the National Science Foundation. It is intended to serve as a facility and resource for cell biologists primarily, but not exclusively, in the northeastern part of the United States; applications from other parts of the country, however, are welcomed.

The Center is headed by Professor Phillips W. Robbins of M.I.T., Dr. Richard L. Davidson from the Harvard Medical School and the Massachusetts General Hospital, and Donald J. Giard, Director. The mission of the Center is to produce cells and viruses on a large scale in order to allow scientists to conduct novel and important experiments in basic cell biology that could not be accomplished with the materials and resources available in the investigator's own laboratory. Special consideration is given to young investigators with limited resources. The Center is working directly with individual scientists on basic research problems and, in addition, is conducting an active program in the development of new techniques for large-scale cell and virus production.

PRODUCTION

During the past year the Cell Culture Center provided cells and/or virus material to 24 research groups in New England as well as other parts of the country. Examples of materials produced during this period include: 130 liters of human lymphocyte cell for Harvard University; 690 liters of HeLa cells for Yale University; RAV-2 virus (476 mg) produced from 663 roller bottles of secondary chick embryo cells for Rockefeller University; 954 roller bottles of HeLa cells for the M.I.T. Center for Cancer Research; 1600 roller bottles of SV-80 cells for Children's Hospital Sidney Farber Cancer Institute; and Moloney Murine Leukemia Virus (1313 mg) from 1300 roller bottles of Cl-1 cells for the Center for Cancer Research.

Cost-Appportioning Program

Effective February 9, 1976, a Cost-Appportioning Program was implemented. Under this new policy, all users are required to pay for the cost of all consumable materials used for their projects. The Cost-Appportioning Program has been well accepted, and at the present time the Center is receiving nearly a 100 percent return on all expendable materials purchased.

RESEARCH AND DEVELOPMENT

The Cell Culture Center has continued its active program in the development of new techniques for large-scale cell and virus production. Considerable progress has been made with the recently developed procedure for synthesizing positive-charge-carrying poly-dextran microspheres. Conditions have been optimized for the growth of a number of different cell types and scale-up work is presently in progress which should lead in the near future to the use of microcarriers for on-going projects.

Feasibility studies on the use of microcarriers to grow human fibroblast cells for interferon production continue, and results to date are encouraging. Interferon titers obtained with FS-4 cells grown on microcarriers indicate that this system would provide an excellent means of mass producing human interferon.

EDUCATION

The Cell Culture Center sponsors a Master's Program in Animal Cell and Tissue Culture Sciences being offered under the auspices of the Interdisciplinary Science Program in the School of Science (Course XXV). The program offers course work in the Departments of Biology and Nutrition and Food Science and laboratory experience in the Cell Culture Center. The program provides students with excellent preparation for vocations that require a broad knowledge of the techniques of cell culture and animal virology. During the past academic year, three students successfully completed the program and two are enrolled for the current term.

PHILLIPS WESLEY ROBBINS

Center for Cancer Research

During academic year 1976-77 the Center for Cancer Research completed its initial development program by bringing its laboratories to full occupancy. The arrival of Professor Michael Bevan, who came to us from the Salk Institute, brings the number of faculty members to 12 as proposed in our original plan.

In the past year, however, the Center received from the National Cancer Institute a grant to remodel 3,000 unoccupied square feet of space in the Seeley G. Mudd Building. This grant, supplemented by others, has made it possible to set up a fine laboratory for the biological

Provost

studies of chemical carcinogenesis. A new faculty member is expected to be brought to M.I.T. to take charge of this laboratory. The National Cancer Institute grant and others have also made it possible to set up an undergraduate teaching laboratory for a course in biology related to cancer. The first such course offered in the new laboratory will be held in fall term, 1977.

The personnel of the Center for Cancer Research has grown to about 150 workers, 120 of whom are in research positions. The Center has attracted 29 graduate students, in addition to a large number of undergraduates doing UROP or summer projects.

SALVADOR EDWARD LURIA

Center for International Studies

The Center for International Studies has continued during the past year to focus its program on international policy issues related to technology and technological change. The Center's efforts to explore the political, economic, social, and institutional dimensions of these issues have led to close research collaboration within the Center among social science, science, and engineering faculties and students at the Institute. In this way, cross-disciplinary research, to which we have long aspired, has increasingly become reality.

The subject of international environmental monitoring has been a major focus of our study. The global environmental effects of industrial, agricultural, and other activities within national boundaries have long been recognized. In many fields, international agencies have established or are contemplating machinery to monitor such transnational phenomena. There are a host of policy problems associated with these efforts: How are environmental issues selected for priority concern? What information should be collected and by whom? Who should evaluate the data and by what standards? What problems arise in translating the results into government action? The answers are not obvious and will differ with specific cases. Initial work is being focused in several areas: depletion of the ozone layer, carbon dioxide and carbon monoxide emissions, and implications of sulphur-dioxide pollution. In addition, work is under way on existing international machinery created to identify and make decisions in the environmental area. Professor George W. Rathjens, Department of Political Science, is directing the program, together with Professor Eugene B. Skolnikoff, Director of the Center for International Studies, and Howard Margolis, Research Associate at the Center. Faculty at Harvard University and Wellesley College also are involved. The research is supported by the Rockefeller Foundation, The Andrew W. Mellon Foundation, and the United Nations Environmental Program.

The future of the nuclear energy industry is the subject of research being done by Professors Joel Yellin (School of Humanities and Social Science), Henry Jacoby (Sloan School of Management), and Paul Joskow (Department of Economics). The projected scale of growth in the industry has raised a host of unprecedented regulatory problems, both national and international. The study is examining the experiences of the United States, the United Kingdom, France, and Germany, with the aims of drawing comparative conclusions and of anticipating future developments. Additional funding has recently been obtained to extend the study to Japan. The project is funded by the Ford Foundation.

During the past year the Center has organized two meetings on common energy related concerns in cooperation with the Max-Planck-Institut zur Erforschung der Lebensbedingungen der

wissenschaftlich-technischen Welt, and the American Council on Germany. The sessions have brought together German and American academics, industrialists, and governmental officials. Additional German-American conferences are being planned and it is anticipated that similar meetings will be held with institutions in France, Japan, and other countries.

The Center has continued its long-standing research on communications, with particular focus on new communications technology and its impact on investment and regulatory decisions, both domestic and international. The research is a collaborative effort with the Center for Policy Alternatives, the Center for Advanced Engineering Study, and the Electronic Systems Laboratory. Professor Ithiel de Sola Pool (Department of Political Science) directs the Center's part of this program, which is supported at the Center by the Markle Foundation. Professor Pool spent the last year traveling in Japan, Southeast Asia, Iran, Israel, and England conducting research on communications problems. Professor Pool also has supervised the preparation of a revised and updated compendium of US laws and regulations in the communications field. The volume, which was authored by Steven B. Rivkin working as a consultant to the Center, will be published in early 1978.

Students of economic development have observed the phenomenon of the dual economy in developing countries -- the coexistence of both modern and traditional economic sectors. At one time the assumption was that the traditional sector would vanish as development proceeded; but this assumption has come into increasing question as similar dualism has been observed in advanced industrial economies. Understanding the economic, political, and social functions of this persistent dualism in Europe and North America has been the objective of research by Professors Suzanne Berger (Department of Political Science), Lisa Peattie (Department of Urban Studies and Planning), Martin Rein (Department of Urban Studies and Planning), and Michael Piore (Department of Economics). The study, which was funded by the Ford Foundation, was completed in the past year. The research group has continued to hold regular faculty-student seminars, and anticipates further work in this field.

Several Center studies over the past year have dealt with other economic-political problems of advanced industrial societies and the international economic system. Professor Douglas Hibbs of the Department of Political Science has been studying long-term trends in industrial conflicts with support from the National Science Foundation (NSF); NSF has also provided funds for a study by Professor Hibbs on public attitudes toward governmental policies on inflation and employment. Professor Lester Thurow of the Department of Economics has been examining the income distribution effects of US exports of agricultural commodities; the Ford Foundation has supported this research. Professor Thurow is planning a companion study of the income distribution effects of agricultural imports, using the United Kingdom as an example. Over the past year Professor Nazli Choucri, Department of Political Science, continued her study of the effects of resource constraints, especially in energy resources, on US interactions with the Soviet Union, Japan, and the People's Republic of China.

The International Nutrition Planning Program (I.N.P.), sponsored jointly by the Center and the Department of Nutrition and Food Science, completed its fourth year. The program has developed a course of graduate study for students from the Departments of Economics, Political Science, and Nutrition and Food Science. Also offered have been a year-long Advanced Study program and shorter-term programs for officials from the US and other governments and international and voluntary agencies. Faculty and students affiliated with the Program have been engaged in a major advisory effort in Pakistan as it implements its national plan to raise nutritional standards, and in a number of shorter-term advisory missions elsewhere on specific nutrition policy problems. Finally, the program has undertaken research on nutrition policy questions. During the past year, a study was continued on the impact of US food aid and trade policies on nutrition in developing countries, and on Pakistan's ration shop system for increasing food availability to low income families.

Dr. Nevin S. Scrimshaw (Head of the Department of Nutrition and Food Science) is Director of the I. N. P. Program. Professor Skolnikoff serves as chairman of the Advisory Committee for the Program; other members of the committee were Professors Richard S. Eckaus (Department of Economics), Lance Taylor (Departments of Economics, and Nutrition and Food Science), Steven Tannenbaum (Department of Nutrition and Food Science), and Myron Weiner (Head of the Department of Political Science). The Program is supported by the Agency for International Development, the Rockefeller Foundation, and NSF.

With a program grant from the National Institute for Child Health and Human Development, and research support from that source and from the Rockefeller Foundation, the Center last year carried out a major series of studies on migration within and among states. Professor Wayne Cornelius (Department of Political Science) studied internal migration in Mexico, with particular emphasis on the effects of Mexican government rural development programs designed in part to reduce presumed incentives to migrate. Professor Weiner explored the impact of municipal, state, and national measures adopted in India to regulate or restrict internal migration. Dr. John Harris, Research Associate of the Center, undertook a comparative study of the development effects of migration in Indonesia and Kenya. Dr. Rosemarie Rogers, Research Associate of the Center, examined the effects on attitudes of prolonged stays outside their home country by European migrant laborers. These studies will continue in the coming year, when work will also begin on: the migration of skilled workers among Arab countries by Professor Choucri; Mexican migrant labor in the US by Dr. Cornelius; and public policies on migration in other Asian countries by Dr. Weiner.

During the past year, work at the Center on arms control focused on problems of nuclear proliferation, especially as affected by new technological developments and the growing importance of nuclear energy generation. The Center also cooperated closely with the Department of Political Science in developing a new Master's program in arms control and defense studies. Other arms control research involved the arms trade, decision making concerning the Strategic Arms Limitation Talks, Soviet civil defense programs and their implications for US defense policy, the role of the Arms Control and Disarmament Agency in formulating US negotiating policy, and the use and misuse of intelligence information in US Congressional debates on arms control and defense matters. Work in this field is supported by the Ford Foundation, the Rockefeller Foundation, and the Cos Cob Foundation. The program is directed by Professor Jack Ruina (Department of Electrical Engineering) with a committee made up of Professors Rathjens, Skolnikoff, Ted Greenwood (Department of Political Science), and Kent Hansen (Department of Nuclear Engineering). This program will continue in future years. It will develop a significant new dimension next year when work is begun by Professor Bernard Feld (Department of Physics) and Dr. Kosta Tsipis (Research Associate at the Center) on a series of studies on military research and development, the nuclear test ban, and information problems on arms control. Their objective is to prepare arms control impact statements on significant new weapons systems (e.g., the MX missile) as well as technologies that may have important military applications in the future.

Work continued by Professor Daniel Holland (Sloan School of Management), with Ford Foundation support, on the rate of return to capital in specific countries. The aim is to find ways to permit systematic comparative study of this question. Professor Holland is currently developing the design of a larger program that will involve coordinated study by several national teams.

The projects and program areas described above constitute the main themes of Center research. Study at the Center also has continued on several topics that have represented major areas of work in the past. Professor Donald Blackmer, Associate Dean of the School of Humanities and Social Science, has continued to study non-ruling parties in Western Europe, with support from the Ford Foundation. Communist and radical movements are the focus of work by Professor William Griffith, Department of Political Science, with support from the Earhart

Foundation. Professor Harold Isaacs, Department of Political Science, has continued his work on ethnicity and ethnic identity, supported by the Ford Foundation and the New World Foundation. Professor Lincoln Bloomfield, Department of Political Science, is researching US foreign policy making, where he has been studying ways in which there can be more effective public input into foreign policy planning; this work is supported by the Kettering Foundation. Finally, Professor Robert Rotberg, Department of Humanities and Political Science, with support from the Edward W. Hazen Foundation, is examining the emergence of black politics in South Africa's homelands.

The Center sponsors seminars on topics related to its research and on general international and social science topics for the M.I.T. community. The Center also publishes a monograph series of research reports. In addition to individual seminars on a wide range of international issues, special seminar series have been held on communications policy, migration policy, and new military technologies.

EUGENE B. SKOLNIKOFF

Clinical Research Center

This has been a year of intensive investigative work at the M.I.T. Clinical Research Center. In addition to studies conducted on individuals occupying the 12 beds, an active outpatient program is under way as well. During the year, the outpatient studies have increased in number so that, at times, some of our nutrition studies will have as many as 100 ambulatory persons under balanced investigation and on special diets and with special blood studies to accompany them. These studies are under the direct supervision of Professor Nevin S. Scrimshaw and his senior colleague, Professor Vernon R. Young, as well as their junior colleagues. These studies are of fundamental importance to our understanding of the nutritional requirements for humans, particularly the amino acid requirements and the relation of amino acid and protein requirements to calorie (energy) requirements. In addition, Professor Scrimshaw and his colleagues are among the major contributors and knowledgeable persons investigating new protein sources conducted in collaboration with the Clinical Research Center.

Professor Robert M. Suskind, Associate Program Director, has had a successful year. Six fellows have been working with him on a number of problems relating to children and children's diseases. These fellows have had a connection with the Children's Hospital Medical Center in Boston. They have some clinical duties and appointments there and at Harvard Medical School, and have made an extraordinarily fruitful collaborative investigative effort. The studies of cystic fibrosis and its nutritional requirements, the problems and treatment of obesity in adolescents, and the nutrition of children with thermal burns have provided us with an opportunity to have two to four children between the ages of eight and 12 years in our Center under careful supervision and, we believe, in an environmental situation far better for growing children than that of a large general hospital.

The Department of Psychology has continued to make important contributions to and use of the Center. It is our great misfortune that Professor Hans-Lukas Teuber died during the year, but his colleagues are continuing the studies. Particularly important are the studies of the cingulotomy operation for pain or for psychiatric illness, most of which have been done at the Center.

Professor Richard Wurtman and his colleagues have been studying the administration of the nutrient choline to patients with Huntington's Disease. Choline, the precursor of the neurotransmitter, acetylcholine, was proposed to enhance the synthesis in the body of the neurotransmitter acetylcholine.

Professor Robley Evans and Dr. Melvin Chalfen of the Argonne National Laboratory, Center for Human Radiobiology, in Phoenix, Arizona, and here at M.I.T., have continued their studies in the Center of bone-seeking radioisotopes in humans. These studies are long-term and appear to be of great importance in our understanding of the effect of isotopes and their handling in the body.

Dr. Ronald Arky, Professor of Medicine at Harvard Medical School and Chief of Medicine at nearby Mount Auburn Hospital, has continued his studies of obesity and the effects of starvation and refeeding on electrolyte and fluid balances.

Dr. George L. Blackburn and his colleagues have developed at the Center a protein-sparing treatment of obesity and have been studying malnutrition in surgical and medical patients with various diseases. The relationship of malnutrition to immunity, which has been one

of their major contributions over the last few years, has been a point of collaboration with Professor Robert Suskind. This work continues to produce important results.

During the year, 27 active projects were conducted at the Center. One hundred forty-seven admissions were made to the Center and 3,784 patient days of care were rendered during the year.

CHARLES S. DAVIDSON

Committee on the Visual Arts (C.V.A.)

The Committee on the Visual Arts is a faculty committee established in 1966 to act as a coordinating body for the varied and growing nonacademic activities in the visual arts at M. I. T., to study the problems of the visual environment of the Institute, and to make recommendations in this area to the President.

During 1976-77 the Committee on the Visual Arts has reviewed its policies and objectives and renewed its commitment to the support of contemporary art and to placing that art in an appropriate critical context. Donlyn Lyndon serves as Chairman. Despite the constraint of a diminished budget, the programs and discussions sponsored by the Committee have been extensive, reaching many constituencies in the Institute and maintaining a lively public presence for the visual arts at M. I. T.

The primary objectives of the C. V. A. are guided by the responsibilities outlined below:

The Committee provides opportunities for the M. I. T. community to have direct experience with contemporary art, and is instructive in the visual arts in a number of ways. The C. V. A. oversees the Permanent Collection and guides its growth. Our interest is to maintain a collection that can serve as a standard of reference for contemporary development and that will support the educational activities in art and the history of art. The Collection is dispersed throughout the Institute in order to enhance the environment and to create frequent opportunities for the Institute community to encounter significant works as indicators of current developments in the visual arts. The Collection also supplements curricular offerings through concentrated exposure to the works of individual artists of recognized achievement, and through comparative exhibitions.

The C. V. A. has maintained and expanded the Catherine N. Stratton Collection of Original Graphics, a loan program established to allow students to select and borrow high-quality original works on paper for their private and public living spaces.

The C. V. A. also is responsible for the organization and administration of exhibitions in Hayden Gallery, Hayden Corridor Gallery, and the adjoining court, as well as in other designated areas. These exhibitions are intended to expose the M. I. T. Community to common themes in the works of a group of artists, and solo shows that illuminate an uncommon approach to visual expression.

Another aim of the C. V. A. is to support promising developing artists through exhibitions and acquisition programs, with a particular reference to those who are in the M. I. T. or Boston community and who are working on issues or in fields that have identifiable interest for M. I. T.

C.V.A. also conducts lectures, symposia, and workshops designed to be instructive to the general M.I.T. community regarding issues and processes in contemporary art.

Committee Action

The C.V.A., while continuing within our mandate to sponsor significant exhibitions with supplementary lectures and explanatory materials, and to foster important acquisitions for the Institute Collection, has established an intensified program to promote experience and understanding of the visual arts and the processes they embody. To make this experience more accessible to the Institute community we have begun this year a variety of educational programs that are designed to communicate more clearly the elements of the artistic process. The Committee also has taken steps to articulate issues regarding the qualitative improvement of the visual environment at M.I.T. and to increase the flow of information concerning completed and proposed projects.

Among the efforts to encourage this wider embracing of the visual arts have been: a concentrated I.A.P. offering including films, lectures, a symposium, exhibitions, and seminars focusing on M.I.T.'s large-scale public sculptures, opportunities to work with a sculptor in the installation of a major piece in the Gallery, and planning for its subsequent reinstallation on the campus; the reinstatement of the student loan collection; the preliminary stages of cataloguing the M.I.T. Collection for documentation in a publication that will encompass not only the artworks but the noteworthy architecture, landscaping, and other cultural factors that complete a total environment; increased dialogue with special interest groups and interested individuals; and involvement in additional exhibition programs at the Institute.

Two previously planned sculpture acquisitions were completed: Works by Henry Moore and Tony Smith were installed on campus, and the year's exhibition program featured works illuminating a variety of aesthetic responses in a number of media. These included: Center for Advanced Visual Studies (C.A.V.S.) Fellow Peter Campus' recent video installations; Boston artist Christopher Sproat's wall reliefs incorporating fluorescent light and electrical hardware parts; a comprehensive selection of Jim Dine's graphic work of the 1970s; two installations of Larry Bell's "Iceberg and its Shadow;" Michelle Stuart's unique earth impressions on paper; and a historical survey of the role of women in American architecture.

Following is a detailed summary of some of this year's Committee activities.

Henry Moore Sculpture. Over the summer, final arrangements were completed to install Henry Moore's "Three Piece Reclining Figure, Draped" in the Killian Court. The C.V.A. staff coordinated the shipment, delivery, and installation with the artist, customs broker, and M.I.T. Physical Plant. The siting was completed in late August.

A ceremony marking the dedication of the sculpture, which was a gift of the Eugene McDermott family and other friends of M.I.T., was held on October 1. Dr. Howard Johnson, Chairman of the Corporation, made introductory remarks and Professor Wayne Andersen, retiring Chairman of the C.V.A., delivered an address capturing the essence of Moore's artistic purpose and recounting his visit to Much Hadam, Moore's estate in England, when the final selection of a work for M.I.T. was made. The sculpture is the third of six bronze casts, and measures 16 feet in length. It was conceived for a prime location in Moore's own sculpture garden and considered by the artist to represent a quintessential distillation of many of the issues he has been involved with throughout his long career. This important acquisition is one of the few monumental Moores in the New England area.

The fall issue of the M.I.T. Art News published by the C.V.A. was expanded to include a detailed text on Henry Moore and a centerfold photo album of the sculpture's installation in process.

Tony Smith. Tony Smith's monumental steel sculpture, "For Marjorie" (1961), was installed in the Westgate area in mid-May. This major event was, like the Moore project, the culmination of a long-term effort to acquire significant large-scale contemporary sculpture for the M. I. T. environment.

The C. V. A. staff coordinated the shipping, foundation design, and installation of the sculpture with Physical Plant. An informal dedication was sponsored by the C. V. A. for the entire Institute community on May 12 with the artist present to answer questions. Provost Walter A. Rosenblith and Professor Lyndon also made brief remarks.

M. I. T. 's "For Marjorie" is a fire-hydrant-red welded steel sculpture measuring 31 x 18 x 17 feet (edition 1/1) and weighing 11 tons. Like Smith's influential works "Marriage" and "Cigarette," it was designed during the early 1960s, a pivotal period in the history of reductivist sculpture. Smith is considered a patriarchal figure among sculptors of the 1960s and one of the first proponents of the "minimalist" movement.

In 1975 Smith came to M. I. T. to review possible sites. A maquette of the piece was later enthusiastically received by the C. V. A. and the sculpture was purchased with the one-percent allotment for New House.

Long-term Loan of Larry Bell Sculpture. A major environmental sculpture "The Iceberg and Its Shadow" by California artist Larry Bell was presented to the Institute on long-term loan by the Albert and Vera List Family Collection. This addition to the M. I. T. Collection possesses a unique capacity for revealing artistic process in a public context and is an invaluable vehicle for immediate and continuous experience of the ideas and issues involved in such an endeavor. As a sculpture consisting of 56 separate plate glass elements, the possible permutations of the Iceberg are virtually limitless. Two different installations were exhibited in Hayden Gallery in January and February 1977. Visitors were encouraged to stop in the Gallery prior to the opening while work was in progress, offering an opportunity for direct exchange with the artist.

Plans are to site portions of the sculpture in configurations shaped by different campus locations. The first public campus installation was completed in April in the lobby of the Sloan School of Management after a studied analysis of the area was made by the artist. Community response was also solicited. The C. V. A. is investigating alternate sites for future placements.

Catherine N. Stratton Collection of Graphic Art. The C. V. A. has succeeded in re-establishing the Stratton Student Loan Collection for the academic year 1977-78. The loan program, active from 1969-73, made available to students an outstanding selection of original contemporary works on paper for their private rooms and public living spaces. The lending program was conceived to aesthetically enhance the quality of students' environments and to foster a continuing appreciation and enjoyment of the visual arts. Because of inadequate funds for artwork and administrative operation, the program was temporarily suspended in 1973.

Several sources of possible funding were investigated. Two work-study students were hired to work under supervision to assess the condition of the Collection and to make simple repairs whenever possible. A supplemental contribution from the Office of the Dean for Student Affairs was obtained. A gift of a large number of framed works on paper from the Albert and Vera List Collection was received in June. All told, the total number of sitable works will approximate 125.

This valuable program, always enormously popular with students, will be restored with an exhibition and lottery to be held in early fall, 1977. In the meantime, proposals for additional funding have been presented to various outside sources to refurbish and catalogue the present Collection; begin an ongoing acquisitions program; and establish a permanent maintenance fund.

I. A. P. Activities

This year the C. V. A. engaged in the most active I. A. P. programming of its history. IAP '77 Sculpture Projects was conceived to bring the community into closer contact with a major focus of C. V. A. efforts: public sculpture at the Institute.

The program's nucleus was the exhibition of Larry Bell's environmental sculpture "The Iceberg and Its Shadow" and a companion corridor show, "Sculptors in other Media," which presented works on paper by sculptors represented in the M. I. T. Permanent Collection.

A seminar with Larry Bell offered participants the opportunity to examine the various considerations that are input for his work. For example, the arrangement and configuration of the segmental plate glass piece are largely determined by Bell's response to the space and character of the site. The use of the Architecture Machine's color computer graphics systems and Visible Language Workshop resources were explored, and contact was established with other departments at M. I. T. whose concerns might be of value -- Materials Science and Engineering, the Center for Advanced Visual Studies, and Architecture (Visual Design) among them. Four sessions were held, with about 20 people attending each. Participants were involved in the Hayden Gallery installation and they discussed the ingredients necessary for future sitings of the sculpture in other public indoor locations on campus.

Other I. A. P. activities included films related to sculpture at M. I. T., and lectures by Carl Nesjar, the C. A. V. S. Fellow who executed Picasso's design for the M. I. T. piece, "Figure Decoupee" and Dimitri Hadzi whose sculpture "Elmo - M. I. T." is located on the terrace outside Hayden Gallery. A symposium on Art in Public Spaces was organized in order to explore issues related to the choice and placement of art from the different points of view of those participating. The panel members were Professor Donlyn Lyndon, moderator; Hugh Davies, Director, Art Gallery, University of Massachusetts at Amherst; Whitney Chadwick, Professor of Art History at M. I. T. and C. V. A. member; Jerome Rothenberg, Professor of Economics at M. I. T. and C. V. A. member; Larry Bell, artist; Arthur Blumenthal, Curator, Dartmouth College Museum and Galleries; Guy Nordenson, M. I. T. student member, C. V. A.

New House Art Allocation

On November 22, 1976, a meeting between New House residents and C. V. A. members and staff was held at New House to discuss the disbursement of funds remaining in the one-percent budget after the Tony Smith acquisition. Professor Lyndon summarized the history of the Smith acquisition and stressed the C. V. A.'s desire for increased communication and collaboration on future projects. Professor Otto Piene, Director of the Center for Advanced Visual Studies, reviewed a proposal to engage kinetic sculptor George Rickey as an artist-in-residence to conceive a piece for New House. Boston sculptor Christopher Sproat made a presentation of his work for consideration. The conclusion that a representative committee of New House students be organized by the students themselves to work with a C. V. A. subcommittee was not realized this year. The C. V. A. has now prepared three alternative suggestions for the consideration of New House residents. Professor James Williams, New House housemaster, is now involved in helping to formulate an effective way to stimulate a decision-making procedure for New House.

Loans to Other Institutions

Several requests were received to borrow works from the M. I. T. Collection for exhibition in corporate and museum galleries. The C. V. A. staff coordinated the administration of these loans. The Sharon Art Center borrowed M. I. T.'s entire Escher Collection for inclusion in a major retrospective in January. A selection of Eschers will also be on view at the Lincoln

Laboratory exhibition space in July. Several major works from the M.I.T. Collection -- the Olitski, Chryssa, Anuszkiewicz, Kozloff, Nesbitt, and Eversley among them -- were part of an exhibition "Corporate Support for the Arts" organized by William Bagnall for the William Underwood Company, Westwood. Joel Janowitz's "Greenhouse Counterpoint" was included in an exhibition entitled "Wellesley Greenhouse" at the Wellesley College Museum in April and Larry Bell's "The Iceberg and its Shadow" will be loaned to both the University of Massachusetts in Amherst and the Federal Reserve Bank of Boston next year.

Other Activities

The C.V.A. program to site pieces from the Permanent Collection in public spaces throughout the Institute continued in full force this year. Most of the 800 paintings, sculptures, and works on paper are sited in lobbies, offices, corridors, and outdoors. Works generally remain in their original site unless recalled temporarily for exhibitions. As new acquisitions arrive, members of the M.I.T. community who have requested works of art are given the opportunity to view them and make selections. The C.V.A. staff advises on the appropriateness for a particular location and takes charge of installation. Occasionally individual departments offer to frame unframed works on paper for siting in their areas. A major effort is also involved in siting large works in main public spaces.

The first phase of the plans for cataloguing the M.I.T. Permanent Collection was completed in December 1976. A National Endowment for the Arts grant enabled the hiring of a cataloguer to assume this responsibility. Each work of art in the Collection has been examined for condition and researched for basic information on the work and artist. The facts have been organized into a system which allows for increased accessibility of data concerning specific objects, improved capacity for monitoring the condition of the Collection, and the orderly reception and accurate recording of newly acquired objects. Proposals have been prepared to publish the catalogue in the form of a walking tour of the Institute's art and architectural resources and a documentation of the ephemeral arts events that have occurred over the years.

Grant proposals were prepared by a C.V.A. staff member for a variety of projects including: the walking tour/catalogue; a one-month artist-in-residency to enable Charles Ross, a sculptor whose work will be exhibited in Hayden Gallery next January, to complete a piece for that show in collaboration with students and faculty in computer graphics and physics; and general assistance for "Paper Forms," an exhibition scheduled to open in Hayden Gallery on September 2, 1977. Staff members also began to pursue the possibility of obtaining CETA (Comprehensive Employment and Training Act) funding to train a gallery manager's assistant, and to find support for the refurbishing, maintenance, and expansion of the Stratton Collection.

One staff member also assisted the Steering Committee of the Arts Discipline group in planning for and drafting proposals.

The Council for the Arts at M.I.T. awarded grants to the C.V.A. for the Peter Campus exhibition. The C.V.A. was also instrumental in obtaining funds from the Council and other sources for a film documenting Larry Bell's stay at M.I.T. The second installation of Bell's "Iceberg and its Shadow" at Hayden Gallery was generously assisted by Albert and Vera List. The Women in American Architecture exhibition, sponsored jointly by the School of Architecture and Planning and the C.V.A., was funded through contributions from a number of architectural firms and interested individuals in the profession.

Professor Lyndon served on a planning committee to formulate a program for the exhibitions space in the new Alumni office complex in Building 10. The C.V.A. staff will undertake the overall responsibility for administering the exhibition program for this space under the direction of a committee chaired by James A. Champy, Executive Vice President of the M.I.T. Alumni Association.

EXHIBITIONS PROGRAM

A diversified program, reflecting the multifaceted nature of the visual arts today and responding to special interest groups within the Institute and in the Boston area, was presented at Hayden Gallery and Hayden Corridor Gallery during academic year 1976-77.

Exhibitions in Hayden Gallery

The season began in early August when Boston sculptor Christopher Sproat turned the gallery into his studio and began building a coherent body of work which related directly to the space. Although the works consisted of materials often associated with Sproat's early pieces, the proportions of electrical tubing and neon light as well as the inclusion of images drawn on the wall represented a new focus. This show, which ran from September 3 to October 2, 1976, was hailed as one of the most important exhibitions mounted in Boston during the 1976 season.

On October 15, "Mask Projections," a group of video works by New York artist and C.A.V.S. fellow Peter Campus, opened to critical acclaim. Three new installation pieces as well as five videotapes from 1973 to the present were included. By concentrating on camera placement, light arrangement, and the distance of the projector from the wall, Campus explored the aesthetic and psychological implications of the medium. An integral part of his conception was the viewer's discovery of his or her own image appearing upside down, which became both a reference to the reversal made on the retina, and a device for transforming the familiar self-portrait. After closing on November 10, portions of the show traveled to the Museum of Modern Art in New York.

"Eight Sheets from an Undefined Novel" were among the 54 works included in the retrospective exhibit, "Jim Dine Prints: 1970-1976." The show reflected the artist's concern with the human figure and self-portrait as manifest in various print media. Thomas Krens, professor of art at Williams College and curator of the show, gave a slide lecture and gallery talk on the artist's development and on the innovative print-making techniques Dine has employed.

Michelle Stuart's exhibition included her journal begun in 1970, large paper scrolls and handmade paper books, as well as a "site drawing" composed of photographs, maps, and earth materials of Sayreville, New York. The artist's inventive method of pounding rocks and earth directly onto rag paper backed with muslin produces varying mineral indentations and tones which approximate the earth's surface and color. The raw materials, though transformed, preserve their earth color, texture, and light allowing for both the history of the geography and of the artist's process to surface.

"Women in Architecture: A Historic and Contemporary Perspective" paid tribute to outstanding female practitioners who, as a minority group, have received little public attention. The first comprehensive inquiry into the professional activity of American women architects, planners, and designers began in the early 1970s as a research project and resulted in a major publication and exhibition organized by the Archive of Women in Architecture of the Architectural League of New York under the direction of Susana Torre. The exhibition consisted primarily of a series of panels of text and photographic material tracing the histories and achievements of women professionals from the late 19th century to the present. Many were among the first women graduates of M. I. T.'s Department of Architecture. The show also included a selection of rarely seen women student thesis project drawings on loan from the archive of the M. I. T. Historical Collections. Slides of recent work of women practicing in the Boston area were assembled for the Hayden Gallery showing, and several faculty and students from M. I. T.'s Department of Architecture participated in the preparation of the exhibition and related activities.

Because of the innovative temper and educational importance of M.I.T.'s Permanent Collection, a number of significant works have been given to the Institute during the last year. These works, including sculptures by Trova and Chryssa, were exhibited from April 15 through 30.

Finally, Larry Bell's monumental color-coated glass environment, "The Iceberg and Its Shadow" opened on January 15.

Exhibitions in Hayden Corridor Gallery

Hayden Corridor Gallery's schedule for the year included the recent photographs of Jonathan Green, former M.I.T. architecture faculty member; serial collages by Ralph Coburn, Graphic Designer, M.I.T. Design Services; a group of oversized graphics; two-dimensional works by sculptors represented in the M.I.T. collection; indigo cloths from West Africa, organized by Marietta Joseph of Boston University's Center for African Studies; portions of the Women in American Architecture exhibition; and selections from the Catherine N. Stratton Collection of Graphic Art.

Publications

The following exhibition brochures and catalogues were published during the year: "Christopher Sproat," an essay by Marjory Supovitz; "Peter Campus," an interview by Marjory Supovitz; "Larry Bell, The Iceberg and Its Shadow: Two Views," a brochure by Martin Friedman; "Michelle Stuart," a catalogue with essay by Robert Hobbs, introduction by Marjory Supovitz, selected bibliography and chronology; "Recent Gifts: Loans and Acquisitions," notes by Kathy Halbreich.

The M.I.T. Art News is generally published at the opening of each year to alert students to subject offerings, exhibition plans, new programs and events. The newspaper informs the M.I.T. community of the broad range of opportunities for participation in the visual arts throughout the Institute, and is a vehicle of information on the history and development of the Institute as a visually concerned environment. For the first time since its inaugural publication in 1972, the September 1976 M.I.T. Art News was expanded to a 12-page format to accommodate reportage of the expanded activities of the C.V.A.

In addition, posters, postcards, catalogues, and other material related to C.V.A. activities are produced in conjunction with M.I.T. Design Services. Material for press releases is prepared by the C.V.A. staff.

DONLYN LYNDON

Division for Study and Research in Education (D.S.R.E.)

The D.S.R.E.'s fourth year has seen further development of individual areas. Of particular importance for the Division has been the clarification and convergence of research interests. The questions now being raised in the Division's research and teaching grow out of previous years' interdisciplinary efforts to understand how the learner learns and how the teacher teaches. The Division's approach to inquiry is characterized by the articulation of the cognitive and affective processes associated with learning, and by careful attention to the educational environment's effects on the intervention between the learner and the teacher and thus on the learning process.

Members of the Division have explored these questions in a variety of settings. M.I.T. undergraduates learning physics and mathematics, eight-year olds and undergraduates constructing a musical tune, learning to program a cybernetic device named "Turtle," designing and testing a computer program for teaching or tutoring students in several different domains. In each situation, the focus continues to be on the learner's learning strategies and how they are influenced by the social reality in which the learning occurs. The underlying question is: How does the learner construct the mental and emotional representation of what is being learned and the situation in which it is learned? This approach stresses the crucial interrelationship between content and context, and generates further inquiries into the fundamental relationships among language, thought, and, ultimately, action. Over the past four years, the Division has sharpened the focus on the connections between the thoughts of the learner, the language used to represent those thoughts, and the actions or the specific behavior that follow from the mental representations of what has been learned.

To further this endeavor the D.S.R.E. has initiated a search for a cognitive psychologist who will have a primary appointment in the Division and an association with the Departments of Psychology and/or Linguistics and Philosophy. The search procedure will involve these two departments and the Division.

The Division received a small grant from the Ford Foundation for Professors Susan Carey, Judah L. Schwartz and Visiting Professor Sidney Strauss to investigate the phenomenon of a decline in children's learning during early schooling. They will prepare an analytic review of relevant literature, experience, and experiments in order to identify possible implications for schools questioning the following assumptions: that, as a student proceeds through school and engages in more and more learning opportunities, his or her acquired skills advance by regular increments; and that there is a smooth transition from one intellectual skill to another in the same way that growth of physical characteristics is continuous.

The Wednesday seminars have continued as a forum for discussion of a range of issues by both Division faculty and students and a number of M.I.T. and outside guests. Of the 25 seminars this year, 18 were led by members of the Division, 4 by other Institute faculty, and 3 by outside guests.

Professors Donald A. Schon and Jeanne S. Bamberger led a weekly seminar which is studying the processes that lead an individual to restructure or to take a new view of a problem, situation, or idea. They see the spontaneous invention of a new metaphor as an instance of such generative processes which yield new perspectives, descriptions, or courses of action. Thus, they are interested in metaphor as a process rather than an artifact of language. Their inquiries center first on efforts to describe rigorously an individual's spontaneous ways of representing a task-situation to him or herself: What does the individual focus on as salient features? How does he/she define an element? How does he/she aggregate and differentiate? How does the individual determine "same" and "different"? The group then tries to observe the transitions and restructurings which lead to transformation in these strategies for making sense of the situation. The experimental situations vary from building simple tunes, to spatial mapping, to investigations of an individual's view of his or her own social setting.

Current research findings suggest that in teaching, more emphasis should be put on making multiple descriptions of the "same" phenomena and particularly on the "coordinating schemas" by which one learns to integrate even initially incongruent strategies of representation. An individual's ability to risk confrontation of such incongruences and to search out the explicit nature of the "mis-match" may be a primary source of learning and creative insight.

Since its inception, the D.S.R.E. has had a close interaction with the work on education of the LOGO group which is part of the Artificial Intelligence Laboratory. Over the past six years LOGO has developed more than 150 subprojects, most of which are carried out in the Children's Learning Laboratory. Small groups of children have participated in a voluntary program of

activities and ways of thinking about teaching and learning. Members of the Division involved with LOGO have been engaged in three kinds of research, all of which require special expertise: 1) developing computer systems (building the material infrastructure for learning environments); 2) reconceptualizing domains of knowledge (developing the knowledge students will learn in these learning environments); and 3) developing theories of learning and instruction for the new learning relationships that become possible.

Daniel Watt, on sabbatical leave from the Brookline Public Schools, joined the Division as a Visiting Research Associate. He has been primarily involved in developing a plan to move LOGO from the laboratory to the school. Planning with the LOGO staff and D.S.R.E. faculty, he has been designing curriculum materials for teachers and students, and consulting with school teachers and administrators. He also has worked with Professor Bamberger in her research into developing curricula in music. The resulting insight into the nature of intuitive musical knowing and its incongruences with the standard descriptions of musical structure will lead to further research in this area and into teacher development.

Lecturers Harold Abelson and Andrea di Sessa have continued their research in developing more intuitive and learnable representation of scientific knowledge. Examining examples of intuitive formulations of physics and mathematics, they used "loud thinking" and other methodologies to explore the way in which students actually represented what they were learning.

At the end of March, the Division sponsored (with funds primarily from the Lilly Endowment, Inc., and some additional support from The Ford Foundation) a conference on institutional studies at Brasenose College, Oxford. Members of the Division and of the Sloan School of Management joined a group of scholars from different parts of the United Kingdom to consider what has been and could be learned from case studies of individual-institutional interaction that have been developed by the group associated with the Division. The participants examined case-study methodology and implications for further research and intervention. Four Americans and four Britons presented papers. A summary of the proceedings has been prepared by D. S. R. E.

The Lilly Fellows Program was extended for a third year by the Lilly Endowment, Inc. Six junior faculty were selected from five departments. While each concentrated on developing their particular projects in their own setting, all worked as a group to explore the context of teaching within a department and within the Institute as a whole. All agreed on the importance of knowing and coping with the setting in which they were teaching and profited from the evening seminars where they explored the institutional milieu.

ACADEMIC PROGRAM

Twenty-six subjects were offered this academic year. The new subjects were: The Cultural Duality of American Minorities: The Educational Process (Special Lecturer Muriel Birchette), Evaluating the Impact of Educational Programs (Professor Karen C. Cohen), Sociological Research: Theoretical Issues and Fieldwork (Professor Sherry Turkle), The Intelligent Eye and the Intelligible Image (Professor Judah Schwartz). Special interdisciplinary courses were: Interdisciplinary Approaches to Cognitive Development (Professor Seymour A. Papert and Visiting Professor Hermina Sinclair-de Zwart), The Role of Metaphor in Learning and Design (Professors Bamberger and Schon), Topics in Science and Mathematics (Lecturers Abelson and di Sessa).

Admissions to the graduate program continue to be joint with other academic departments. Three students were jointly enrolled with Electrical Engineering and Computer Science; two each with Psychology, Urban Studies and Planning, and the Sloan School of Management; one each with Mathematics, Architecture, Physics, and Linguistics and Philosophy. Two new graduate students enrolled this year bringing the total to 14, 12 of whom were enrolled in the doctoral program and two in the master's program of Course XXV. The latter two graduated in June.

INTERACTION WITHIN M. I. T.

The links between the Division and other units of M. I. T. continued to multiply. New joint appointments were arranged this year with the Departments of Psychology, Humanities, Chemical Engineering, and Electrical Engineering and Computer Science, while a joint appointment with the Humanities Music Section was renewed. Members of the faculty of the Sloan School have increased their participation in the Division, particularly in the area of institutional studies.

Project WITS, which moved to the Division just over a year ago, is working on improving the transition for men and women from education to work. A seminar series was sponsored in the spring on "Changing Opportunities for Women." Visits to industrial sites have been conducted in order to expand understanding of work options in technology and science. School teachers, counselors, and administrators have observed industrial employees at work, and industrial hosts have developed a greater appreciation of the potential for expanding their relationships with schools, the source of their future work force. The Project confronts the need for increasing female participation in all aspects and levels of our technological society. WITS is supported by the Massachusetts Department of Education, the Alfred P. Sloan Foundation, the Fleischmann Foundation, and the National Alliance of Businessmen.

INTERACTION OUTSIDE M. I. T.

The Division's past and current work involving computers (i. e. LOGO, Computer as Coach, and an ethnographic study of computer culture) was the subject of discussions with the Texas Instruments Company. An exchange of visits has occurred and Texas Instruments and the Division are exploring which kind of relationship would be mutually beneficial.

The Education Development Center (E. D. C.) of Newton has taken an interest in LOGO. Starting with the basic work of LOGO done by Division faculty and graduate students, E. D. C. has been exploring the design of a program for teaching teachers and developing curriculum materials.

The Division's working relationship with Austin College has continued and developed. Professor William T. Martin was a visiting professor there during February and March. Professor Papert visited Austin College to advise the Departments of Psychology, Education, and Mathematics. Professor Schon assisted and advised the college officials on their program management project. The Division's research into institutional studies has been used by them in reviewing recent changes at the College. Presently they are studying the possibility of incorporating the work of the LOGO group into several of the College departments.

The link with the Oxford Educational Research Group at the University of Oxford continued this year. Professor Jerome Bruner and Dr. Harry Judge visited the Division for two weeks in fall term. As noted above, Professor Bruner lectured on "Thought, Language, and Social Context," and Dr. Judge explained the work of the Oxford Educational Research Group. During spring term members of the Division met in Oxford with members of the Oxford Educational Research Group to discuss the Case History approach to Institutional Studies.

The Division has continued to benefit greatly from its visitors. These included: Sir Robert Birley, Professor and Head of the Department of Humanities and Social Science, City University, London, England; Dr. Jerome Bruner, Department of Experimental Psychology, Oxford University, England; Dr. Harry Judge, Director of the Department of Educational Studies, University of Oxford, England; Dr. Anthony Ryle, Director of the University Health Service, Sussex University, England; Dr. Bertrand Schwartz, Professor of the Science of Pedagogy, University of Paris, France; Dr. Hermina Sinclair-de Zwart, Department of Psychology, University of Geneva, Switzerland; Professor Pinchas Tamir, Amos de-Shalit Science Teaching

Center, Hebrew University of Jerusalem, Israel; Sir Geoffrey Vickers, Goring-on-Thames, England; Research Fellow Sylvia Weir, Department of Artificial Intelligence, University of Edinburgh, Scotland; Professor Martin Trow, Director of the Center for Study in Higher Education, Berkeley.

PERSONNEL

Muriel Birchette completed her two years as a Special Lecturer. Drs. Abelson and di Sessa have been promoted to Assistant Professor. New members of the Division included: Karen C. Cohen, Visiting Associate Professor; Sidney Strauss, Visiting Associate Professor; Stanley Russell, Lecturer; Daniel H. Watt, Research Associate. James H. McCarthy was appointed Administrative Officer in January 1977.

Elaine Medverd left M. I. T. after three years of significant service in D. S. R. E. first as Administrative Officer, then as Assistant to the Director.

BENSON R. SNYDER

Harvard-M.I.T. Program in Health Sciences and Technology

ESTABLISHMENT OF THE HARVARD-M. I. T. DIVISION OF HEALTH SCIENCES AND TECHNOLOGY

In the spring of 1970, the Corporations of M. I. T. and Harvard, the faculty of M. I. T., and the faculties of Medicine and of Public Health of Harvard approved plans for the establishment of a joint Harvard-M. I. T. institution "to foster the development of health-related programs of education, research, and service between the two institutions." The decision was then made to create a joint Program in Health Sciences and Technology (H. S. T.),* develop appropriate curricula, design an organizational structure, and acquire necessary supporting funds. The experience of the past seven years demonstrates that the two universities can join successfully and productively in common efforts to teach the health sciences and technology. From the beginning, however, it has been recognized that an appropriate stable institutional structure is essential to the full achievement of the Program's objectives.

Such an institutional structure should: 1) be an integral part of the two universities; 2) provide a framework for interdisciplinary education and research efforts and for the development of new professions such as medical engineering and medical physics; 3) facilitate the appointment of necessary new faculty members and the development of necessary new facilities; 4) provide attractive career opportunities for those faculty members whose primary commitment is to the achievement of the Program's objectives; and 5) provide visibility for the commitment of the two universities to this joint enterprise, thus enhancing the chances of obtaining the requisite financial support.

An administrative and academic structure which meets these criteria is an inter-university division within the faculty of M. I. T. and within the faculty of Medicine at Harvard. The Harvard-M. I. T. Division of Health Sciences and Technology was established by the votes of the Corporation of M. I. T. and of the President and Fellows of Harvard College in June 1977.

*Detailed appendices on such areas as the organization and governance of H. S. T., admissions data, and curriculum requirements may be found in the Archives edition of this report.

The educational programs of the Division include: 1) a curriculum developed and administered in concert with the faculty of M.I.T. and Harvard's faculty of Medicine, leading to the M.D. awarded by Harvard University. This curriculum prepares students with special interests and qualifications in physical, engineering, biological, and other quantitative sciences for careers as physicians, and thus unites the knowledge and skills derived from science and technology with medical research and practice, 2) a curriculum leading to Master's, Engineering, and Doctoral degrees which will prepare engineers and scientists for careers in medical engineering and medical physics involving the application of advanced science and technology to the understanding, prevention, and control of human disease and disability.

Programs in research and development will be concerned with important biological, medical, and health related problems which can best be addressed in an interdisciplinary manner through the collaborative efforts of scientists, physicians, and engineers from the two participating universities.

The organization and administration of the Division are outlined below:

Governance. Responsibility for the formulation of educational, administrative, and fiscal policies is vested in a Governing Board whose membership will consist of the President and one member of the Corporation of M.I.T. and one other person selected by them, and the President and one member of the Harvard Corporation and one other person selected by them. The Governing Board will authorize major programs of instruction and research, appoint a Visiting Committee for the Division, and review and approve the annual budget of the Division.

An Administrative Council will include the Provost of M.I.T., the Dean of the Harvard faculty of Medicine, the Director of the Division of Health Sciences and Technology, the Dean of the Harvard faculty of Arts and Sciences, the Dean of Engineering and Applied Physics at Harvard, the Dean of the Harvard School of Public Health, the Dean of the School of Engineering of M.I.T., and the Dean of the School of Science of M.I.T. The Council will oversee the implementation of approved programs in the participating faculties and schools, review plans for new educational and research programs of the Division, and discuss plans for new educational and research programs in other schools or faculties of the two universities relevant to the Division's activities.

The development and conduct of H.S.T.'s academic programs are the principal responsibilities of the Joint Faculty Committee. Membership in this Committee will consist of those members of the faculties of M.I.T. and Harvard having major educational, research, and administrative functions within or in relation to the Division of H.S.T. Members will be appointed by the Director of the Division of H.S.T., with the advice of the Administrative Council. The Joint Faculty Committee will 1) determine criteria for appointment of the faculty of the Division; 2) establish requirements for new faculty and staff positions whose primary responsibility is to H.S.T., and initiate requests for appointments to meet these needs; 3) request and receive reports from faculty committees established to implement the academic programs of the Division; 4) maintain liaison with related activities of M.I.T. and Harvard through service on appropriate committees of each institution.

Rules and regulations for appointments and promotions to the faculty of the Division have been established in conformity with the principal regulations of the faculties of the two universities. Significant differences have been reconciled. It will be the policy of the Division of H.S.T. to develop and conduct its programs primarily with faculty who are appointed to positions in either or both M.I.T. and Harvard. When necessary, faculty members may be appointed whose primary responsibility is to the Division of H.S.T.

EDUCATIONAL PROGRAMS

Biomedical Sciences Curriculum

A new subject "Topics in Quantitative Physiology" has been developed by Professors Felix Villars, Thomas Weiss, William Deen, and David Litster. It was offered for the first time in fall term of 1976 and deals with principal processes and regulatory mechanisms in cellular physiology. It is offered as a basis for more advanced study in pathophysiology in which physical approaches to normal and abnormal physiology of specific organ systems are emphasized. The subject has received highly favorable and enthusiastic review by the students and by the Curriculum Committee. There is need, however, to appoint one or more physiologists to participate actively in the development and teaching of this subject.

Students in the curriculum are expected to engage in independent study and to submit a thesis prior to graduation. For approximately one-fourth of the students the independent study means working for both a Ph.D. and an M.D. A critical need, yet to be met adequately, is the provision of funds to support students seeking the M.D. and Ph.D. Stipends currently available from the National Institutes of Health (NIH) supported programs at Harvard Medical School fall far short of meeting the needs of these students. The support of the M.I.T. Health Sciences Fund and gifts from private donors have been of great help in meeting these requirements. It is clear, however, that for the long term, an increased number of funded positions in the N. I. H. supported M. D. - Ph. D. Program will be required.

Admission of students into the M.D. curriculum is determined by a faculty committee of which Dr. Herman N. Eisen, Professor of Biology at M.I.T., is chairman. This committee serves as a subcommittee of the Admission Committee of Harvard Medical School. During the past year there were 450 applicants for 25 positions. One hundred and forty of the most promising applicants were interviewed by two members of the Admission Committee. It is gratifying to observe the very high quality of the applicants and the extraordinarily fine records of those selected for admission.

The third class of Harvard-M.I.T. students to receive the Doctor of Medicine degree graduated in June 1977.

Medical Engineering and Medical Physics Curriculum

The objective of this curriculum is the education of persons highly qualified as engineers or physicists with extensive knowledge of human biology and medicine, who will be well qualified to engage in clinical investigation of important problems in medicine. Such individuals should be capable of engaging in creative scholarship which would provide a base for the development of the profession of medical engineering and medical physics -- a profession concerned with the application of science and technology to clinical medicine and the delivery of health care. The curriculum has evolved from the work of two committees. Professor Ernest G. Cravalho of M.I.T. has been chairman of a committee consisting of faculty members of the Schools of Engineering and Science of M.I.T. This Committee developed the overall curricular plan and the procedures and policies governing admissions and general examinations for the doctoral degree. The second committee consisting of faculty members of M.I.T. and Harvard Medical School and the Massachusetts General Hospital was under the chairmanship of Dr. Richard Kitz. It was concerned with the development of the clinical experiences which are an integral part of the educational program.

In March 1977, the faculty of M.I.T. voted to establish new Ph.D. and Sc.D. programs in Medical Engineering and Medical Physics. These new doctoral programs will be offered for the first time in academic year 1978-79.

This report should take special note of the most important contribution which has been made by David W. Hamilton, Lawrence J. Henderson Associate Professor of Health Sciences and Technology and Associate Professor of Anatomy at Harvard Medical School. Professor Hamilton served as chairman of the Curriculum Committee and developed the outstanding course in functional anatomy as well as the course in reproductive biology. As a major contributor to the development of the biomedical sciences curriculum and as a principal advisor to H.S.T. students, Professor Hamilton was a creative force in the evolution of the H.S.T. Program. He is leaving to assume the Chairmanship of the Department of Anatomy at the Medical School of the University of Minnesota, a major academic position appropriate to his scholarly achievements and administrative skill. He leaves this community with the warm gratitude and best wishes of the faculty and students of H. S. T.

Two endowed chairs have been established in the Division of H.S.T. with a gift by the Matsushita Electric Company of Japan. The Matsushita Professorship of Mechanical Engineering and Medicine has been awarded to Professor Cravalho, and the Matsushita Professorship of Electrical Engineering and Medicine has been awarded to Professor Roger G. Mark, each of whom has played a key role in the educational and research activities of H. S. T.

The Grover Hermann Professorship of Health Sciences and Technology has been established at M.I.T. by a gift from the Grover Hermann Foundation. Dr. Irving M. London, Professor of Medicine at Harvard Medical School and Professor of Biology at M.I.T. and Director of the Division of H.S.T., has been appointed the first Grover Hermann Professor of Health Sciences and Technology.

Dr. Deen has been appointed Assistant Professor of Health Sciences and Technology and Assistant Professor of Chemical Engineering at M.I.T. Dr. Jeffrey Harris has been appointed Assistant Professor of Health Sciences and Technology and Assistant Professor of Economics at M.I.T.

RESEARCH

Current research activities and the principal investigators of each are as follows: An Interdisciplinary Program in Biomaterials Science, Professor Robert W. Mann; Biomedical Engineering Center for Clinical Instrumentation, Professor Mark and Dr. Stephen K. Burns; Cryopreservation of the Isolated Rat Heart, Professor Cravalho; Nuclear Techniques in the Study of Metabolism and Bone Disease, Dr. S. James Adelstein and Professor Gordon L. Brownell; Optimization of Dose Distribution in Cancer Radiation Therapy, Dr. Martin B. Levine and Professor Henry M. Paynter; Rehabilitation Engineering Center, Dr. William Berenberg; Studies on Conduction and Demyelinated Central Axons in situ, Dr. Stephen G. Waxman; Short-Lived Radiopharmaceuticals for the Diagnosis and Treatment of Disease, Dr. Adelstein and Professor Brownell; Regulation of Hemoglobin Synthesis and Hematopoiesis, Dr. London; Thromboresistant Materials, Dr. Edwin W. Salzman.

Three major new interdisciplinary research programs are being developed. After two years of planning, a program has been formulated on health effects of fossil fuels utilization with particular emphasis on environmental carcinogenesis and mutagenesis. The overall objective of this program is the development of a series of data bases on which assessment of potential health consequences, particularly the total burden of environmental carcinogens and mutagens resulting from combustion of fossil fuels, can be made with greater objectivity and precision than is currently possible. The program includes combustion studies for health effects of particulates, thermo-chemistry of inorganic combustion particulates, analytical chemistry for combustion, experimental determination of the biological effects of combustion products, and

systematic carcinogenic evaluation of coal combustion. The Principal Investigator is Professor Gerald N. Wogan and the Co-Principal Investigator is Professor Jean F. Louis. Dr. Irving A. Bernstein is Executive Officer.

A program for computer assisted clinical application of localized hyperthermia in the treatment of malignant disease is being developed. It involves new ultrasound and microwave instrumentation for delivering heat and monitoring tissue response during treatment, the development of a computer controlled system which computes the distribution of tumor destruction and then modifies heating to optimize tumor destruction. The directors of this program are Professors Cravalho and William V. McDermott, Professor of Surgery at Harvard Medical School.

A program of research on learning disabilities in children and young adults is being formulated and developed. The objective of this program is the study of diagnostic criteria and methods, the etiology and pathogenesis and the remedial measures and treatment of various cognitive disorders. This program involves neurologists, pediatricians, physiologic psychologists, psycholinguists, psychiatrists, computer scientists in the field of artificial intelligence, and experts in education. Dr. Melvin D. Levine, Assistant Professor of Pediatrics at Harvard Medical School, is playing a leading role in planning this research effort.

Dr. Bernstein, Assistant Director for Research Program Development, Dr. H. Frederic Bowman, and Keiko Oh have been principally responsible for the organizational and administrative aspects of these research efforts. Douglas C. Johnston is the Executive Officer for the Rehabilitation Engineering Center and Edward Sadowski is the Administrative Officer for the Biomedical Engineering Center for Clinical Instrumentation.

Financial Resources

As of June 30, 1977, endowment funds received or pledged totaled \$7.8 million of which \$1.1 million was raised during this year. Operating funds received in 1976-77 totaled \$367,246. Since 1970, approximately \$21.1 million have been raised, \$7.8 million for endowment, \$2.3 million for operations and facilities, and \$11.0 million for research and development.

Dr. Walter L. Koltun, Assistant Director for Resources, is in charge of these activities in the Division.

In view of their close association with the activities of the Division of Health Sciences and Technology, M.I.T.'s fund raising for Health Sciences, Technology and Management should be noted. During the past year two major grants have been awarded to M.I.T.: The Glenmede Trust Company of Philadelphia has made an award of \$9 million, and the Whitaker Foundation has made an award of \$10 million for the construction of a Health Sciences Center and Health Services Center on the M.I.T. campus. The Health Sciences Center will include major M.I.T. components of the Harvard-M.I.T. Division as well as new programs in Human Biology, Human Physiology and Experimental Medicine, and Health Care Policy and Management. The planning and design of these new facilities have begun.

IRVING M. LONDON

Independent Activities Period (I.A.P.)

In 1977, the Independent Activities Period proved it could withstand not only the worst of winters but also the test of time. Despite January's severe snowstorms, participation in I.A.P. 1977 remained as high as in previous years, and in the spring a review of the past seven years by the I.A.P. Policy Committee showed that I.A.P. has remained vital and strong and is making an important contribution to the Institute.

The snowstorms which played havoc with the eastern half of the United States this past January scrambled the schedules of I.A.P. activities, particularly during the first week and a half. At first it was feared that many activities would be cancelled, but most meetings were rearranged. The scheduling flexibility inherent in I.A.P. made it possible for participants to overcome the blizzards; in the end, only about 10 percent of the 514 activities listed in the Final I.A.P. Guide were cancelled, a rate comparable to that of preceding years.

Similarly, student and faculty participation in I.A.P. seemed as high as in other years. Students responding to the Policy Committee's annual questionnaire reported that they were on campus most of the time during January. More than 65 percent of the undergraduates and 75 percent of the graduate students said they were on campus 75 percent of the time or more during that month. Their statements were supported by dormitory and fraternity occupancy counts, which also showed that an average of 75 percent of the residents were on campus over the three and one-half weeks of I.A.P. Among faculty members, over 85 percent of the respondents to the questionnaire reported on-campus attendance 75 percent or more of the time during I.A.P.

As in earlier I.A.P.s, faculty members and graduate students reported that most of their time was devoted to their usual work. Faculty members reported spending an average of 70 percent of their time on work in their usual areas of concentration.

However, more than 65 percent of the respondents did have an opportunity to engage in new and different activities. Graduate students said that they spent an average of 55 percent of their time on regular academic work, and more than 10 percent in independent study and non-credit academic work. By contrast, undergraduate respondents said they spent more than 25 percent of their time in independent study and non-credit academic work and slightly more than 10 percent in regular academic work.

Although the 514 activities published in the Final Guide represented only some of the projects under way during I.A.P., they were important indicators of the effort and commitment that members of the M.I.T. community made during January. Of the activities listed in the Guide, 363 (or 71 percent) were academic or semi-academic in nature. Approximately 40 percent of these were led by faculty members, 34 percent by staff members, and 26 percent by students. More than half involved substantial commitments of time and effort, with meetings scheduled weekly or more often; one-fourth met twice or three times during I.A.P., and the remainder were one-time events, such as lectures.

Beyond statistics, however, these activities continued to display a rich variety in format and topic, indicative of the creativity and dedication of members of the M.I.T. community. Mini-courses, lecture series, laboratory sessions, seminars, round-table discussions, hands-on shop projects, field trips, workshops, films, research projects, and contests of all kinds were initiated. Many of the offerings were of a serious and technical nature. Some examples are a weekly seminar on "Recognition System of T-Lymphocytes," a daily mini-course on "Field

Methods in Articulatory Phonetics," and five lectures making up "A Week of Mathematical Logic." Other projects involved students in the practical application of principles they had learned in their regular course work. Some efforts, like the one to build "Big Board," a rotating electrical message board, attracted 20 students, while others, such as the project to devise a "New Type of Fluidic Logic Element," had a single student working under the direction of a faculty member.

A number of faculty members, like the biologist who taught a seminar on African art or the physicist who organized a four-day symposium on "Archaeoastronomy-Astroarchaeology," used I.A.P. to offer activities outside their regular fields of interest. Sometimes departments called upon experts to give advice to the lay person about everyday problems, as in Mechanical Engineering's "Consumer Guide to Clothing," or Nutrition and Food Sciences' "How Much to Eat, of What, and Why." Through lessons offered in I.A.P. 1977, students were able to acquire a wide range of skills including surveying, machine-shop work, typing, cooking, science fiction writing, and motor maintenance. They were able to improve themselves physically through Athletic Department classes, which were offered in more intensive form than in the regular semester. Sometimes an individual was able to get a group of like-minded people together to pursue the same interests, such as the eight musicians who spent January practicing 15th-century Flemish music on instruments of the period, and then gave a free concert on the last day of I.A.P. Even the fun oriented events like the College Bowl and the Scrabble Bee, which displayed the imagination and skill of their organizers, raised community spirit and provided a change of pace.

After I.A.P. 1977 ended, the Policy Committee, with the aid of the I.A.P. Administrative Committee, prepared a 54-page progress report for the Committee on Educational Policy as required by the 1973 faculty vote which continued I.A.P. in the regular academic calendar of the Institute. Entitled "Trying One's Wings: Seven Years of I.A.P.," the report briefly reviewed the Institute's total experience with I.A.P. but mostly focused on the use faculty members and students have made of their time during the past four intersessions. It included the extent to which they have taken advantage of the increased opportunities for concentrated or independent work and for flexibility in learning and teaching.

In reviewing I.A.P., the Committee found that its data remained remarkably consistent over the past four years. The above-mentioned statistics on faculty and student attendance on campus, faculty and student use of time during January, and the types of special activities offered are all similar to those for the previous years.

In regard to faculty participation in Guide activities, the Committee found that each year about 270 faculty members or 30 percent of the total faculty have been listed in the Guide as activity organizers, seminar leaders, lecturers, and panel members. They have come from all three ranks of the faculty in approximately equal proportions. To determine if the same faculty members have been carrying the burden of Guide activities year after year, the Committee also compared the names of faculty members listed in the Guide and found that in any one year from 40 to 50 percent of the faculty were different from those of previous years. The only concern the Committee expressed over faculty involvement in Guide activities was with a decline (from 34 to 27) in the percentage of the total faculty participating in Guide activities during the past four years; a parallel decline occurred in the number of Guide activities led by faculty members. Nevertheless, the Committee believed the level of faculty participation has remained satisfactory and noted that the slack in faculty led activities has been picked up by an increase in the number led by staff members and students.

Over the past four years, faculty as well as student attitudes toward I.A.P. have been overwhelmingly favorable. About 90 percent of the faculty respondents to the annual questionnaire found I.A.P. personally beneficial while close to 80 percent thought I.A.P. a good idea for the Institute as a whole. In the first year of I.A.P. full professors did not support I.A.P. as strongly as did members of the other faculty ranks; however, over the years their support has increased almost to the same level as that of the rest of the faculty. From the beginning, students have

been strongly in favor of I. A. P. Well over 90 percent of the undergraduates responding to the surveys thought I. A. P. a good idea, not only for themselves personally but also for the Institute as a whole. Graduate students have been only slightly less enthusiastic.

While the specific content of the I. A. P. Guide differs from year to year, the public activities have not changed in richness and variety. Instead of becoming stale with age, I. A. P. has remained important as a time of creativity and experimentation for members of the M. I. T. community. As the I. A. P. Policy Committee noted in its report:

"For this year's cover of the I. A. P. Guides, a freelance artist created a cartoon character who now has come to be known affectionately as the 'I. A. P. Person.' The figure is a student laden with activity gear -- camera, snorkel, running shoes, slide rule -- fiercely pedaling a unicycle to achieve the acceleration needed to lift off on homemade wings. The I. A. P. Person first appeared on the cover of the Announcement in October. By December, when it was time to issue the Final Guide, the idea arose that this time the cover should show the I. A. P. Person aloft, having attained full flight, with the discarded unicycle lying prone and useless on the ground like the spent propulsion stage of the launch vehicle of an Apollo mission.

"The metaphor of the two cartoons was not premeditated, but nevertheless for many, I. A. P. is a time to try one's wings -- and to do so at relatively low risk, because the commitments involved are provisional and short-term. This is a rare opportunity for the young or the not-so-young, for the apprentice or the journeyman. For many, I. A. P. has expanded horizons and opened up new areas of knowledge or new interests and avocations. For some, it has led to entirely new choices for first and even second careers. For all, I. A. P. has continued over seven years to offer a wide choice of academic or personal opportunities that contribute to a balanced full academic-year program at M. I. T."

Based on its review of I. A. P., the Committee made only one recommendation -- that the 4-1-4 calendar with I. A. P. be continued without change in the regular academic calendar of the Institute. The Committee also suggested that a similar review be made within the next four years. The Committee on Educational Policy approved the report, and it was received favorably by the faculty at its meeting on April 20, 1977.

I. A. P. policy is supervised by a faculty-student committee appointed by the President. Members of the I. A. P. Policy Committee this year were: Professors Michael S. Feld (Chairman), Woodie C. Flowers, Jean E. Jackson, Merton J. Kahne, Harvey F. Lodish, George Wolf, Theodore Wood, Jr., Mark S. Wrighton; Timothy C. Aareset, Dean James J. Bishop, Joel Orlen, Cordelia M. Price, Peter J. Reynolds, Margaret S. Richardson, and Charles H. Shooshan III.

Responsibility for I. A. P. administration is placed in the Office of the Provost and is accomplished through rotation of staff from departments and other offices of the Institute. This year the I. A. P. Administrative Committee included: Mr. Orlen (Chairman), Richard J. Caloggero, Mary Enterline, Professor Feld, Victor M. Maslov, Dr. Louis Menand III, Ms. Richardson, Jane Sauer, and William Westcott.

JOEL ORLEN

Joint Center for Urban Studies

This was a year of consolidation and growth at the Joint Center as plans for strengthening the research agenda, made in 1975-76, came to fruition. Projects have been under way in an expanded housing agenda which now encompasses the related areas of housing finance, consumer preferences, and the effects of cyclical instability on the construction industry.

The urban setting remained the focus of research this year, particularly in the areas of land use and the delivery of public services, but now the program has been extended to include studies at the state and regional levels as well. Migrations of people and firms in and out of the country's regions and the changing industrial environment were major topics under consideration this year. The inquiry into social stratification in America and social policy research was concluded within the year, and now the investigators are concentrating their energies on publishing the enormous amount of information generated by the project.

The most newsworthy even of the year was the publication of The Nation's Housing: 1975-1985, the report of a project directed jointly by Professor Bernard J. Frieden, the previous Director of the Joint Center, and Professor Arthur P. Solomon, the present Director, both of the M. I. T. Department of Urban Studies and Planning. Response to the publication has been substantial among academics, industry leaders, and national policy makers. Of Joint Center Working Papers which were in the public view, the paper coauthored by Professor Frieden and Marshall Kaplan, "Community Development and the Model Cities Legacy," was particularly timely and well received. A critique of past urban development programs, it led to a day of testimony on Capitol Hill before the House Subcommittee on Housing and Community Development. Other work described below, such as research on the welfare system, social policy, and social structure, has also been the subject of interest among policy makers in Washington.

HOUSING POLICY RESEARCH

The Nation's Housing: 1975-1985

The study codirected by Professors Frieden and Solomon was designed to assess and forecast the nation's housing needs for the next decade. It complements the original report, America's Housing Needs: 1970-1975 (David L. Birch, et al., 1973) by broadening the scope of the analysis and extending it five more years into the future.

The new document contains three sections. In a forecast of the residential construction requirements for the entire United States and each of its major regions, Professor Solomon aggregated and analyzed data on individual housing markets in order to estimate construction demand through 1985. It was projected that we will need between 20.23 and 22.58 million units to meet household growth and to accommodate other market pressures. Incorporated into this count were the results of two other Joint Center projects, on population migration and household formation, described below. In an assessment of the extent and nature of housing and neighborhood deprivation, Professor Frieden extended the 1973 study at the Center to include information on the neighborhood inadequacies affecting middle- and low-income families alike. His estimate of 4.0 million households dissatisfied with street and neighborhood conditions was added to the 12.8 that were living in physically inadequate units, overcrowded, or suffering from high rent burdens. The authors also discussed another, less visible form of deprivation, the current and future cost squeeze facing home buyers. The high cost of housing represents a newly emerging problem as only 25 percent of the nation's households can now afford to purchase a median-priced home.

Simulation Model for Migration

A three-year project on interarea migration ended in March 1977. Funded by the US Department of Housing and Urban Development (HUD), Dr. David L. Birch (Senior Research Scientist, Joint Center) and his team replicated the simultaneous processes by which people and changing employment opportunities adjust to one another. Projections of the model, which simulates interregional migration patterns, indicated important shifts of population to the South, to

medium- and small-sized cities, and to nonmetropolitan areas. The number of people who will move into the four main geographic areas of the country and the amount of housing that will have to be built for them are published in the report, The Nation's Housing.

Study of Household Formation

The ways people choose to live have important implications for the types of housing they require as well as for the number of units necessary to shelter them. Dr. John Pitkin (Research Associate, Joint Center) designed a behavioral model of the important relationships involved in the formation of households of various types and sizes. Based on historical trends, Dr. Pitkin calculated that about 11.9 million additional households will be formed by 1985. This is 1.7 million lower than the lowest figure projected by the Census Bureau (Series C), whose methodology Dr. Pitkin questioned in the report, The Nation's Housing.

Neighborhood Change

Principal Investigator Dr. Birch and a team of researchers funded by HUD designed and tested a second model to help clarify the neighborhood factors in housing deprivation and to serve as a planning tool for the future development of urban centers.

The Joint Center model, like its predecessors, includes such factors as natural increases and migration, housing vacancies, employment location, and school change. But this model does not incorporate the usual notion that long-run equilibrium can be achieved in metropolitan housing markets. Instead, it presents the housing market as a more organic system constantly shifting in response to changes in employment location, transportation systems, and population characteristics, and includes the concept that people do not behave as "near-perfect information processors and maximizers." For these reasons, imperfections rather than maximizing behavior dominate the dynamics of market changes such as swings in construction rates, discontinuities in housing prices, and rapid shifts in neighborhood composition.

The work proved that rules of behavior which apply to most cities can be constructed and that, by using neighborhood-by-neighborhood data on population characteristics, employment, housing, schools, and land use, the development of a city can be better understood.

The Costs of Controlling Cyclical Instability

Research Associates Dr. Carol Corrado (Federal Reserve Board) and Dr. Thomas Cooley (National Bureau for Economic Research and the University of California at Santa Barbara) have been examining the historical relationship between housing and countercyclical stabilization policy. After assessing the relationships among government monetary policy, the mortgage market, and housing construction during the 1960s, they developed a series of optimal control experiments with monetary policy as the primary instrument of control to see whether they could maintain a constant level of housing starts while keeping unemployment and inflation under control. They found that they could reduce the variability in the Gross National Product by reducing the variability in housing starts alone. This part of the experiment suggested that the whole economy could benefit if the housing sector alone were stabilized. In the year to come, the researchers will extend their inquiry through the development of an even more elaborate model of the housing and mortgage markets. Funding for the project has come from the National Chamber Foundation.

Alternative Mortgage Instruments

The Nation's Housing acknowledged the role of mortgage reform in helping low- and moderate-income families and young first-time home buyers gain access to homeownership. The Joint Center received funding from the Federal Home Loan Bank Board and the Federal National Mortgage Association for a year's study of alternative mortgage instruments. The study contained three parts.

- 1) The Borrower Study. The first task was to distinguish which features of the proposed mortgage plans would be the most desirable to different subgroups within the population. Through the use of panel discussions and a national survey of borrowers' attitudes toward various mortgage features, Professors Solomon and Kent Colton (Department of Urban Studies and Planning, M. I. T.) examined the importance of financial considerations in the decision to buy a home and the method of financing it.
- 2) The Lender Study. Concentrating on savings and loan institutions, Professors Richard Cohn and Donald Lessard (M. I. T. Sloan School of Management) analyzed both the asset-liability portfolio implications for those who lend mortgages and also the default characteristics of designs for alternative mortgages.
- 3) The Secondary Market. Mark Waltch (Joint Center Research Associate) assessed the role of alternative mortgage instruments in the secondary mortgage market and their potential for sales to private financial institutions, insurance companies, and government sponsored agencies. He examined the existing secondary mortgage market and the pricing of current mortgage instruments, the potential secondary market investors, and the implementation processes needed for packaging, forming mortgage pools, issuing certificates, and providing the necessary guarantees.

The Disintermediation Function: A Monthly Forecasting Model

Thrift institutions are periodically drained of a portion of their deposits through what has been called the "disintermediation function." Funded by the Federal Home Loan Bank Board, Professor Kenneth Rosen (Princeton University), a Faculty Associate of the Joint Center, has been studying the savings flow of funds in and out of savings and loan associations in an effort to understand the role this process plays in the cyclical instability of the housing market. Professor Rosen has improved upon earlier simulations of savings flows by developing an explicit model that includes estimations of gross instead of only net flow; examining the functional form of the disintermediation function; examining regional differences in the sensitivity of savings flows to fluctuations in interest rates; and using these results to develop a monthly forecast model of savings flows to savings and loan associations.

A Short-Run Model of Housing Cycles

Cyclical fluctuations in the housing industry, caused in part by disintermediation, can be distinguished from the seasonal fluctuations experienced within a year's span. To find ways of modifying swings in construction activity, Professor Rosen has developed an econometric model of housing starts. It includes several innovations such as a disaggregation of housing by type of unit and by region, a causal approach to the seasonal adjustments of the industry, and the incorporation of recent structural changes in financial intermediaries and government intervention techniques.

URBAN AND REGIONAL DEVELOPMENT

Regional Development and the Changing Industrial Environment

This year marked the beginning of a new research agenda focusing on the problems of state and local economies. The first team of researchers, interested in the interaction between institutional change and economic development, studied the effect of air and water pollution control regulations on regional investment as well as intrametropolitan industrial location. Roger Schmenner (Harvard Business School) tested several hypotheses concerning recent changes in patterns of work-place location in New England and around Cincinnati, Ohio. Robert Leone (Harvard Business School) explored the ways in which industry cost structures impact on location patterns. Joint Center Associate Director John Jackson, the principal investigator, examined the response of the executive and legislative branches of the Federal government to the intra-industry and interregional distribution of income, wealth, and employment opportunities resulting from a selected number of public policies. Funding for this phase of the work came from the Economic Development Administration of the US Department of Commerce. Some results from an earlier phase of the study have already been published in Robert A. Leone, Environmental Controls: The Impact on Industry (D. C. Heath, 1976).

An Econometric Model of Business Locational Decisions

In August 1976 Professor Dennis Charlton (Joint Center Faculty Associate at the University of Chicago) completed his investigation of the factors that influence an industry's choice of location. Funded by the Lincoln Institute of Land Policy and using data from Dun and Bradstreet, he developed a model that can predict the impact of regional and national government policy decisions on the economic incentives for businesses to relocate. The factors he considered in his model of the births, deaths, and migrations of firms included differential costs in wages, transportation, land, and taxes; land-use restrictions; environmental controls; and availability of labor and energy resources. So far, three papers from the project are in manuscript form: 1) "Locational Decisions of Manufacturing Firms" (introduction to the analysis); 2) "Births of Single Establishment Firms and Regional Variation in Economic Costs" (description of data); and 3) Models of Single Establishment Births (preliminary estimates of a locational model for the plastics industry).

The Fiscal Crisis in American Cities

Professor William Wheaton (Departments of Economics and Urban Studies and Planning, M.I.T.) compared America's large cities with their suburbs in terms of their fiscal condition. He found that increases in the cities' taxes and expenditures, caused mostly by spiraling municipal wages, have left cities in an exceedingly weak fiscal position. The criteria Professor Wheaton used for evaluating the fiscal health of the 19 cities were related to municipal taxes and spending. He intends to pursue this research in the future.

The Effects of Government Regulation on Industrial Location and Regional Development

Professor Daniel Shefer of the Technion-Israel Institute of Technology in Haifa was a Visiting Scholar at the Joint Center this year. His research to date focuses on understanding the structural determinants of depressed areas in the United States.

SOCIAL STRATIFICATION AND SOCIAL POLICY

The research program begun in 1970 to examine social structure and living standards in America was in its final investigative stages this year. Directed by Professors Lee Rainwater and Christopher Jencks of the Department of Sociology at Harvard and Professor Martin Rein of the M. I. T. Department of Urban Studies and Planning, the research has explored the distribution of personal well-being in modern society and the distribution of social and economic resources for achieving a measure of well-being. Funding has come from the US Department of Health, Education, and Welfare (HEW), the Ford Foundation, the German Marshall Fund, and the US Department of Labor.

The research activities, which include comparative studies in nine European countries, are now in the process of publication in several forms. They were divided into four major areas, the first of which distinguished the determinants of male economic success. Several different surveys which constituted the data for this study were reconciled so that the researchers could examine the effects of family background, mental characteristics, schooling, and experiences in the labor force on the occupational opportunities of men and, consequently, on their incomes. Part of the study is being published in a forthcoming book by Professor Jencks and his colleagues, Who Gets Ahead? (Basic Books, 1978).

The second major task for the project was to analyze the determinants (and amounts) of family income. The data source, the Panel Study of Income Dynamics from the University of Michigan Survey Research Center, contains information on the lives of men and women aged 24 to 54 in 1968, the first year of the survey. How they put together a livelihood out of wages, transfers, benefits, and other income sources has been detailed in the Joint Center's work on income packaging. The interim report, "Sources of Family Income and the Determinants of Welfare" (May 1976), contains the description of the cluster analysis techniques used in the study and some preliminary results.

Policy makers have been interested in the project's analysis of the families that received welfare during the survey period, in particular the conclusion that the "welfare class" is really a very small portion of all people who receive welfare payments. How much assistance welfare recipients get and how their income packages compare with the packages of other low-income families are issues again discussed in the interim report cited above and in two Joint Center Working Papers to be published later in 1977. The extent to which people combine income from work and income from welfare was considered by Professors Rein and Bennett Harrison (Department of Urban Studies and Planning, M. I. T.). The first stage of the investigation, published in the Joint Center Working Paper number 40, counted the women who cycle on and off welfare for different lengths of time. It noted that independent labor market conditions seem to influence the way these women use the welfare system. Professor Harrison's research continued through the year with funding from the Center for the Study of Metropolitan Problems at the National Institute of Mental Health. It included variables to help account for the supply and availability of welfare, the extent of intercounty and interstate migration connected with change in welfare status, and the availability of forms of financial support other than either welfare or earnings.

Joseph Swartz (Harvard) reported on the individual components of family income in Professor Jenck's forthcoming book mentioned above, and Professor Rainwater described the sources of these components, along with the three other aspects of total family income (personal, participation, and gains), in an unpublished paper, "A Model of Family Income." Models of the determinants of each of the components of family income, which have been completed during the past year, are presented in his "Social Class Placement: Quantitative and Qualitative Approaches Part II: Exploration of the Correlates of Qualitative Assessments of the Social Class of a Sample of the PSID Families: A Discriminant Analysis" (unpublished).

Qualitative, "clinical" analyses by Susan Anderson-Khleif of Wellesley College (on families headed by women), and Richard P. Coleman, Joint Center Senior Research Associate, were assembled to complement the statistical material and will be included in the final publication connected with the project.

The dimensions of social class and social resources (e. g. , education, occupation, income) formed the third area of research. A series of qualitative analyses on this subject appear in Professor Rainwater's unpublished paper "Quantitative Approach to the Study of Life Style: Plan for Continuing Research and Pilot Study," as well as his "Social Class Placement" paper. The fourth part of the social policy and stratification project was an investigation of social consumption and life style. Again described in Professor Rainwater's two papers, this analysis deals with ways to specify quantitatively the relationships among particular aspects of a family's cultural, social, and economic resources. The social class aspects of the project are the subject of another book to be published in 1978, Richard P. Coleman and Lee Rainwater, Social Standing in America (Basic Books).

URBAN EDUCATION AND SOCIAL STRUCTURE: 1880-1925

The relationship between social mobility and background and educational attainment in the past is another aspect of American social structure analysis under way at the Joint Center since September 1976. Professor Stephan Thernstrom (Department of History, Harvard), as Principal Investigator, and Ari Joel Perlmann (Research Associate, Joint Center), as Co-Investigator, have chosen to focus on the primary and secondary education of the lower part of the social hierarchy in Providence, Rhode Island. Funded by the Center for the Study of Metropolitan Problems of the National Institute of Mental Health, their major task between October 1976 and May 1977 was to collect the data in computer files and to formulate their major analytic variables (ethnicity, class of origin, structure of family of origin, educational attainment, type of school attended, and economic attainment).

DELIVERY OF PUBLIC SERVICES

Public Employee Unions and Urban Services

Central cities depend for their services upon public employees who are increasingly becoming unionized and increasingly escalating their financial and political demands. Formally launched in June 1974, the project exploring the emergence and rapid rise of these organizations, their objectives, and their impact on employment and service delivery drew to a close at the end of June 1977. Four case studies concentrating on the description and analysis of relations between public employees and their management and the impact of their unions on the delivery of public services have now been completed. One is a Joint Center Working Paper (number 41), "Future Challenges in Teacher Collective Bargaining," by Charles Cheng (University of California at Los Angeles) who has also written a book on the subject. The other three are: "Dollar for Dollar: A Study of the Cost of Living Escalator in the Los Angeles Fire and Police Pension System," by Janet Corpus; "There's No Place Like Home: A Police Union's Struggle Against the Residency Requirement in Detroit," by Judy Levinson; "Holding On: Union Resistance to Civilian Employees in the Boston Police Department, 1968-1969," by Frederika Randall.

Four more studies still in process describe pension reform and wage determination in Los Angeles, pension reform in Detroit, and hospital workers in Boston. The project's Co-Director, Professor Robert Fogelson (Department of Urban Studies and Planning, M.I.T.), received funding from the Center for Studies of Metropolitan Problems of the National Institute of Mental Health (the sponsor of the entire employee union project at the Joint Center) for a book on the subject, Big City Police (Harvard University Press, Summer 1977). The other Co-Director, Dr. Ralph Jones of Contract Research, Inc., has summarized the findings of the work, which are now available from the project in an assessment of the general impact of unions on such issues as personnel recruitment and labor costs (Ballinger Publishing Company, forthcoming).

The Politics of Street-Level Bureaucracy

Professor Michael Lipsky (Department of Political Science, M.I.T.) has completed his research on the problems faced by the "street-level bureaucracies" that provide services to the public. Funded by the Russell Sage Foundation, Professor Lipsky developed a general theory of the provision and delivery of public services in which he focused on the points of interaction between the public employees who actually deliver the services and the citizens who require them. By combining interviews with participants in the system, systematic direct observation, and an analysis of the records, he studied different levels of utilization, structures, and adaptations that account for differential processing and treatment of citizens and the reasons for the relative success or failure of the citizens' search for service. Having completed the first draft of a book-length manuscript to be published by the Russell Sage Foundation, Professor Lipsky is continuing work on a secondary study of the provision of legal services, coauthored by Gary Bellow, Jean Kettleon (Harvard Law School), and Carl Hosticka (State University of New York Law School at Buffalo). Another subsidiary project, on special needs education reform in Massachusetts, received additional funding from the Bureau for the Education of the Handicapped at HEW. Professor Lipsky and Richard Weatherley described the frustrations of trying to implement the well-intentioned but prohibitively expensive and time-consuming educational law, Chapter 766, in a Joint Center Working Paper (number 44) with an abbreviated version in the Harvard Educational Review.

SEMINARS

Luncheon Seminars

Again, one of the most successful of the Joint Center's ongoing programs was the series of luncheon speakers invited to address the Joint Center community. The policy makers and faculty members who spoke were William Alonso (Director, Center for Population Studies, Harvard); Hubert E. Jones (Professor, Department of Urban Studies and Planning, M.I.T.); Thomas P. O'Neill III (Lieutenant Governor, Massachusetts); William Wheaton (Faculty Associate, Joint Center and Associate Professor, Department of Urban Studies and Planning, M.I.T.); Ulf Christiansen (Professor, University of Copenhagen and Senior Research Associate at the Danish Building Research Institute); and Kenneth A. Gibson (Mayor of Newark, New Jersey).

Regional Science and Urban Policy

The Joint Center continued to cosponsor a seminar with the World University of the World Academy of Art and Science. Directed by Professor Walter Isard of the University of Pennsylvania for the faculties of Harvard, M.I.T., University of Pennsylvania, and Cornell University, it began with a lecture by Dr. Alonso. Other contributors were Professor Isard, Richard Olsen (Charles River Associates), and Professor Brian Berry (Harvard).

The Joint Center and the World University also cosponsored two one-day conferences, the Economic Future of the Northeast States (January 19, 1977) and World Energy Models (May 20, 1977).

Family, Population, and Policy Seminar

With a view to developing a new research agenda, the Joint Center and the Center for Population Studies at Harvard initiated the Family, Population, and Policy Seminar in spring, 1977. Adopting the premise that policies affect the behavior of families, members of the Boston community interested in the relationship of family life and population trends and policy formulation gathered to articulate the ways in which family structure and behavior react to certain policy measures. Under discussion, for example, were issues related to housing policy because changes in household membership over the life course of its members are seen to interrelate with changes in the housing market. Speakers at the sessions included Mary Jo Bane and Ronnie Retner (Wellesley College, Women's Research Center) who discussed the legal and economic responsibilities of family members to each other; George Masnick (Center for Population Studies) and John Pitkin (Joint Center) speaking from an historical and demographic perspective of the recent changes in family structure; Tamara Hareven (Center for Population Studies) and George Masnick on the flows of birth cohorts in and out of different family configurations and roles as they relate to changing historical conditions; and Laura Lein (Center for the Study of Public Policy) and Robert S. Weiss (Laboratory of Community Psychiatry) on single parenting and parenting in families having two working adults.

Urban Growth and Development

The Joint Center, the National Bureau of Economic Research, and the Lincoln Institute of Land Policy cosponsored a conference, "Alternative Forms of Urban Growth and Development," on June 9 and 10, 1977. Additional grants for the conference came from the Alcoa Foundation and PPG Industries.

The main purpose of the conference was to bring together leading scholars, industrialists, labor leaders, bankers, and government officials to discuss, explore, and contribute to the creation of an urban development agenda for the nation. The topics under consideration were the different economic, social, technological, and demographic changes that will affect the spatial structure and growth of our metropolitan areas, the consequences of these effects on various population groups, and the responses expected from public policy makers to balance between the nation's needs for growth and development and its needs for quality of life.

The papers, given by William Alonso, Roger Schmenner, Ira Lowry, George Peterson, John Kain and William Apgar, Richard Babcock, Bernard Frieden, Gregory Ingram, and Thomas Pettigrew, will be published in a book edited by Professor Solomon.

Graduate Seminars

Two seminars for graduate students of Harvard and M.I.T. met at the Joint Center. The first, Sociology 230 (Harvard): Sociological Aspects of Public Policy, was given by Professors Rainwater and Rein. The students were asked to design research projects based on the eight-year Panel Study conducted by the Survey Research Center of the University of Michigan, which forms the core of data used by the two professors in their Joint Center study of social stratification and social policy.

The second seminar, Economics 2800 chf (Harvard), was conducted by John F. Kain, John R. Meyer, and Gregory Ingram. Discussions were based on presentations of ongoing research in urban economics, transportation, and regional economic development.

FELLOWSHIP PROGRAM

The research topics of the eight students chosen as Joint Center Fellows reflected and expanded the research agenda at the Center. Among their dissertation subjects were the urban fiscal crisis and municipal employee unions, regional development strategies, and working class recreation in Worcester, Massachusetts (1870-1940).

John Jackson, Associate Director, led the Fellows' seminars. Those who presented the substance of their research were: Mingche Li, "A Dynamic Model of Moving Behavior and Tenure Choice;" Robertson Williams, "Household Formation and Housing Demands;" Barbara Brenzel, "The Girls at Lancaster: A Social Portrait of a 19th-century Reform School for Girls;" and Roger Bernstein, "Class Action and Judicial Economy. "

ECONOMIC ADVISOR TO THE PRESIDENTS OF HARVARD AND M.I.T.

Economic Advisor for the term ending in December 1976 was Dr. Penelope Schafer, formerly of the Department of City Planning at Harvard. For the last six months she undertook an evaluation of the fiscal impact that the two universities have had on the city of Cambridge.

SURVEY RESEARCH PROGRAM

The Survey Research Program, cosponsored by the Joint Center and the University of Massachusetts, has continued work on its extensive list of survey projects. Among the largest is Life Problems and Alcohol Use in an Urban Population, a four-year project funded by the National Institute of Alcoholism and Alcohol Abuse and directed by Thomas W. Mangione (Survey Research) and Norman Scotch (Boston University). Another project, headed by Floyd J. Fowler, the Director of Survey Research, is the Reduction of Crime and Fear, funded by the Hartford Institute of Crime and Social Justice.

The City of Boston has funded a cooperative venture between the Boston Urban Observatory (BUO) and Survey Research. Thomas Mangione and Joseph Slavet (BUO) are conducting a feasibility study for a multi-service center in Mattapan. The Alternative Mortgage Study at the Joint Center (described above) has also contracted the services of the Survey Research Program for the borrower surveys that form the core of data for the study.

Laurence J. Branch continues his work on the health care needs of the elderly in Massachusetts, and Floyd Fowler and Thomas Mangione are now finishing their study of the impact of anti-gambling laws on the criminal justice system. During this year Floyd J. Fowler, together with the United Community Planning Corporation and the Combined Jewish Philanthropies, finished an analysis of the social, educational, recreational, and health needs of residents in the Boston metropolitan area.

Among the publications released by Survey Research this year are: Floyd J. Fowler, 1975 Community Survey: A Study of the Jewish Population of Greater Boston (Boston: The Combined Jewish Philanthropies of Greater Boston, 1977); F. Fowler with C. Cannell, "Interviewers and Interviewing Techniques," in Advances in Health Survey Research Methods (Washington, D. C.: HEW-PHS, 1977); F. Fowler with F. Pratter, "Police Perceptions of Gambling Law Enforcement," in Gambling in America, Appendix 3 (Washington, D. C.: Commission on Review of the National Policy Toward Gambling, 1977); Thomas W. Mangione with F. Fowler, F. Pratter, and C. Martin, "Citizen Views of Gambling Enforcement," in Gambling in America; and Laurence G. Branch, "Determining the Needs of the Elderly and Chronically Disabled," New England Journal of Medicine, 294:2 (1976), 110-111.

Publications

During the past year, staff members of the Joint Center published seven books, seven working papers, and one report. The Center has continued to publish its Research Report, a newsletter which comes out three times a year. This year, numbers 11-13 were sent to a list numbering close to 1,200 in October, February, and April

ARTHUR P. SOLOMON

Laboratory for Computer Science

The Laboratory for Computer Science is an M. I. T. interdepartmental laboratory, whose principal goal is research in computer science and engineering.

Founded in 1963 as Project MAC (for Multiple Access Computer and Machine Aided Cognition), the Laboratory developed the Compatible Time-Sharing System (CTSS), one of the first time-shared systems in the world, and Multics -- an improved time-shared system that introduced several new concepts. These two major developments stimulated research activities in the application of on-line computing to such diverse disciplines as engineering, architecture, mathematics, biology, medicine, library science, and management. Since that time, the Laboratory's objectives expanded, leading to a broad front of research activities that now span three principal areas. One of these is making programs more intelligent by capturing, representing, and using specific knowledge. Examples are the use of "expert medical knowledge" for assistance in diagnosis and for drug administration carried out by the Clinical Decision-Making Research Group; the use of mathematical knowledge by the Mathlab Research Group for an automated mathematical assistant; and the use of knowledge in a specific domain in order to comprehend typed natural language (English) in that domain.

A second main focus of Laboratory research is making sizable improvements in the ease of utilization and cost effectiveness of computing systems. For example, the Programming Methodology Research Group strives to achieve this broad goal through structured program-

ming, i. e., by imposing constraints on the programmer. Toward the same goal, the Domain Specific Systems Research Group is exploring the programming of micro-computer systems from higher-level, domain-specific languages for the control of physical processes. Other research examples in this area include the study of large data bases, the architecture of individual "personal" machines, and the organization of geographically distributed systems of computers. The latter are studied by the Computer Systems Research Group from the point of view of exploiting the decreasing costs of processors and memories, improving overall performance and reliability, protecting information, and ensuring privacy.

The Laboratory's third principal area of research involves exploration and development of theoretical foundations in computer science. For example, the Theory of Computation Research Group strives to understand ultimate limits in space and time associated with classes of algorithms, while the Computation Structures Research Group searches for a combination of appropriate programming languages and machine architectures that ensure trouble-free asynchronous computation by several processors. Other research in this area includes the Semantics of Programming Languages from both analytical and synthetic viewpoints.

During the past year, the Laboratory consisted of approximately 200 members -- 30 faculty, 52 support and professional staff, 85 graduate and 28 undergraduate students -- organized into 14 research groups. The academic affiliation of most of the faculty and students is with the Department of Electrical Engineering and Computer Science. Other departments represented in the Laboratory membership are Mathematics, Architecture, Humanities, and the Sloan School of Management.

Laboratory research during 1976-77 was funded by nine governmental and industrial organizations.

The 1976-77 year was quite active. Technical results were disseminated through the publications of the Laboratory members and will not be discussed here. Highlights of the year included the following:

The Laboratory's Distinguished Lecturer Series, initiated last year, has been quite successful in attracting members of the M.I.T. community. The 1976-77 lecturers under this series have been Professors Michael Rabin, C.A.R. Hoare, Joseph Traub, Frederick Brooks, and Niklaus Wirth.

The nationwide Study on the Long-Range Future of Computers and Information Processing, with contributions from 20 distinguished scientists and engineers, is in manuscript form and will be published by the M.I.T. Press in mid-1978. The study strives to identify likely and desirable trends in computer hardware, software, and applications, as well as in the potential societal implications of the projected technical developments.

Several large meetings were held by the Laboratory's members to discuss new research possibilities in computers for the home, individualized desk-top large-capacity machines, and geographically distributed systems. The home computers are aimed at home-bound (either by choice or by necessity) individuals and entail educational, recreational, and office-in-the-home services. The desk-top large capacity machines are intended for the Laboratory's members' research. Their over-one-million-word memory capacity is necessitated by the trend toward large programs, already evident in our research results on expert programs and on natural-language understanding programs.

The area of geographically distributed systems is beginning to form a major Laboratory focus. Such systems are of interest since people and the generation of information are by nature geographically distributed, and since the costs of computing and connecting computers

continue to decrease. Potential problems in this area are many and may, in effect, limit the otherwise natural growth of distributed systems. As a result we are exploring a wide variety of research problems on the reliability, robustness, and efficiency of these systems. The experimental Laboratory network, which was conceived last year, is progressing satisfactorily. It strives to interconnect the Laboratory's computational resources, thereby offering a useful service and a testbed for experimenting with distributed systems.

Another major development in 1976-77 has been the cooperation of our Laboratory's Computation Structures Group with members of the Lawrence Livermore Laboratory (LLL), Livermore, California, for the purpose of designing computationally powerful (asynchronous, parallel) machines based on the data-flow ideas of Professor J. B. Dennis. These machines promise to be 100 times faster than today's fast machines. Their applications will be in weather forecasting, signal (picture) processing, and in the solution/simulation of four-dimensional multi-variable partial differential equations. We are pleased with this association since LLL has considerable experience in the problems suitable for large machines, and we have experience in machine architecture.

Professor Sherry Turkle, a sociologist, has joined us as an associate member of the Laboratory. Her interests are on the impact of computers upon the individual. We feel that the societal aspects of computers and information processing already are, and will become progressively more important in the future. Professors Turkle and Joseph Weizenbaum represent a Laboratory strength in this important area.

During 1976-77 research in previously established areas yielded several new results and insights in 1) automated mathematical assistance, where we strive to aid scientists and engineers through programs such as MACSYMA for the symbolic manipulation of mathematical expressions; 2) natural language understanding, by computer programs, where we strive to develop programs (and associated theories) that comprehend typed statements in relatively narrow domains of discourse; 3) clinical decision making, where in cooperation with physicians at the New England Medical Center we study and experiment with the acquisition, representation, and use of specialized medical knowledge for the purpose of aiding diagnosis and facilitating drug administration; 4) theory of computation, where the methods of discrete mathematics are brought to bear on a variety of computational problems for the principal purpose of characterizing the optimal amounts of time or space required to carry out computations, to analyze the power of different computing machine organizations, and to analyze the mathematical properties of programming languages; 5) programming language semantics and computer architecture, where we are developing novel structures and associated theories in order to exploit parallelism and asynchronous computation, and where we try to provide sound semantic foundations for programming languages and computer architecture; 6) computer systems research, where we seek to understand and develop reliable, robust, and efficient geographically distributed computer systems; 7) micro-computer applications, where we are concerned with the programming of real-time (micro) computers for control and instrumentation from higher level languages; 8) large data bases, where we try to develop theories and techniques associated with the storage, upkeep, and access of massive data; and 9) knowledge-based communications, where we try to detect messages (e. g., Morse Code) beyond the capabilities of electronic filters, through use of a good deal of knowledge about these messages, such as an English vocabulary and the sender's wrist-action characteristics.

Our results in these areas were published through Laboratory technical reports (TR164-TR182) and technical memoranda (TM72-TM85), as well as through articles in the technical literature.

MICHAEL L. DERTOUZOS
JOEL MOSES

Libraries

The past year was one of considerable progress in the M.I.T. Libraries. While continuing to provide information in diverse forms and on a variety of subjects to the M.I.T. community, the Libraries' staff invested a great deal of time and effort in analyzing existing services and programs and planning new ones. Among the major internal concerns that consumed attention were collection development; reserve collections and services; library information publications; long-range space planning; conservation; and staff development. Members of the staff also were involved in a wide range of activities involving M.I.T. and the library profession. Most noteworthy in this regard were the programs and future plans of the Boston Library Consortium and of various other networks and consortia to which the Libraries belong such as NELINET (New England Library Information Network) and NASIC (Northeast Academic Science Information Center); events of the 1977 Independent Activities Period; and participation in regional and national meetings. Within the Libraries there was a conscious effort to effect a higher degree of coordination and centralization with a concomitant increase in efficiency of use of both human and material resources. It is gratifying to report that much progress has been made toward attainment of this goal, yet there is a realization that much remains to be done. The staff of the M.I.T. Libraries has responded with enthusiasm and imagination to the challenges that confront universities and their libraries today. Their willingness to participate in information gathering and policy formulation is sincerely appreciated.

PERSONNEL

Under the administrative reorganization effected last year, the responsibility for personnel activities with the exception of professional recruitment and advancement was assigned to the Assistant Director for Administrative and Personnel Services. One of the principal activities planned by that office was a series of workshops on performance evaluation conducted by the Office of Personnel Relations. The results as evidenced by the report of the workshop director, and by the comments of the supervisors and staff members who attended, were highly successful. The Advisory Committee on Librarian Staff Development, chaired by the Director of Libraries, continued to work on policies covering serious search procedures, evaluation of librarians, appointment, and promotion. The Committee expects to present a draft of the new policies to the entire professional staff early in fall, 1977. The Associate Director of Libraries Margaret A. Otto, who serves as Affirmative Action Officer, updated the Libraries' goals as part of an Institute-wide project in June. She also continued to work on refining the Libraries' procedures for external recruitment. An unusually high number of retirements and resignations generated the appointment of many search committees. The policy of including staff members outside the department directly involved, as well as members of the faculty, has proved quite successful. Faculty members have served on the committees searching for the Institute Archivist, Humanities Librarian, and Aeronautics and Astronautics Librarian, and their participation is greatly appreciated. A major goal for the fall review of search procedures will be an analysis of applications by source in an effort to identify the most productive avenues for attracting qualified candidates.

The Libraries were particularly hard hit by retirements and resignations this year. Five members of the staff with a total of 101 years of service retired by the end of June, led by

Eleanor L. Bartlett (38 years) and Barbara C. Darling (35 years). Professor E. Neal Hartley resigned as Institute Archivist on December 31, 1976, and later retired as Professor of History. On the incoming side of the ledger was the appointment of the first full-time Institute Archivist at M.I.T., Helen W. Slotkin, formerly Special Collections Librarian at the University of Cincinnati. A complete record of appointments, promotions and transfers, resignations, and retirements for the professional staff is at the end of this report as is a record of staff activities during the past year.

Collection Development

The Libraries' aim of establishing a comprehensive and coordinated set of policies for collection building responsive to the needs of teaching and research at the Institute was given momentum during the year through a number of activities. The Collections Development Librarian, working closely with the heads of divisional and branch libraries, began setting up guidelines for the formulation of collection development policies. Decisions were reached to 1) move gradually from department oriented to subject oriented collections, 2) adopt model policy guidelines developed by an American Library Association committee for written acquisition statements including definitions of collection levels, and 3) develop general procedures for formulating policies for specific subjects. The first draft policy, for psychology, has been produced as a result of these discussions. Additional policy statements are currently in preparation for collecting on law of the sea and mineral resources. Eventually, statements must be produced for all areas of collecting interest. The purpose of these policy statements is to assign primary collection responsibility and to identify levels of acquisition for the libraries involved with each subject area.

While the work described above will certainly have an immediate and positive effect on the Libraries' efforts to deal with the dual pressures of inflation and increased publication, a project of major importance in the area of collection development was initiated late in the year. It is one that could have far-reaching impact not only on the M.I.T. Libraries but on research libraries in general.

The M.I.T. Libraries have been invited to participate in a Collection Analysis Project sponsored by the Association of Research Libraries under a grant from the Andrew W. Mellon Foundation. As one of three libraries in the country to be so recognized, the M.I.T. Libraries will, during the six months from July to December 1977, make a major effort to analyze and improve the procedures for collection development. The goals of the project are to 1) develop a mechanism for the formulation of collection policies, 2) determine the equitable allocation of resources, and 3) measure the effectiveness of collection programs. Funds provided through the grant will permit the appointment of a full-time research assistant to work with the Collections Development Librarian, who is directing the project, and with a study team of library staff responsible for coordinating the project. The study will include, in addition to the goals cited above, the testing and modification of a manual on collection analysis which, when published, should prove to be of considerable value to other research libraries engaged in similar activities.

Cataloguing

Despite what can only be described as a Herculean effort by the entire staff of the unit, the Catalogue Department was frustrated in its attempts to reduce significantly the processing arrearage. A combination of staff turnover (100 percent in the Library of Congress [LC] Cataloguing Section) with an unprecedented amount of down time and malfunction in the automated system along with a surge of incoming material late in the year resulted in a decrease in cataloguing output. It is evident that staff cuts in this area during the past few years have

Libraries

taken their toll, and serious consideration is being given to several alternatives for solving this pressing problem.

Even with the problems cited above, the Catalogue Department was able to make substantial progress in a number of important areas. Most crucial were the publication of the 14th edition of Serials and Journals in the M.I.T. Libraries (last published in 1971), establishment of new policies and procedures for cataloguing M.I.T. technical reports, screening and transfer of continuing serial titles from the old (Dewey) catalogue to the new catalogue, updating procedure manuals, planning for participation in serials cataloguing through the Ohio College Library Center, design of new work forms and statistical reporting forms, and expansion of the pre-catalogue system to encompass microforms and non-print materials. With a stable staff situation, an anticipated settling-down of the automated system, and, most important, the continued dedication of the staff, the prognosis for continued improvement in this area is excellent.

Public Services

Under the leadership of Suanne W. Muehlner, Assistant Director for Public Services, the Public Services Group, consisting of the heads of the divisional and branch libraries, made substantial progress in a number of problem areas. They were deeply involved in the development of collection policies and in the identification and establishment of levels of service that should be provided to M.I.T. users as compared to those outside the Institute who have access to the collections. The Group spent a great deal of time analyzing the effects of M.I.T.'s membership in the Boston Library Consortium and developing guidelines for use by individuals from member institutions. Continued attention was given to the matter of security and the possible adoption of a book detection system in the Student Center Library. Following on the work of the Reserve Task Force, some progress was made toward standardization of reserve policies and procedures. A new form was devised for submission by faculty of required reading, and a decision was made to remove from the Student Center Library reserve collections for subjects with small enrollments and to rely upon the divisional and branch libraries for service to these classes.

One of the most salutary developments this year was the establishment of the Library User Relations Committee with responsibility for the coordination of user education activities throughout the system. The Committee has identified the Libraries' most urgent needs for instructional materials and will produce several publications by the beginning of next term. These include a revised library guide and information handouts on reserves, circulation policies, schedules of hours, how to find various types of materials at M.I.T., and an index of special equipment. The redesign of the library guide from a handbook into a series of brochures and information sheets featuring specific library services will do much to provide improved and current information.

The Libraries' computerized literature searching services provided through the NASIC program continued to expand in both number of searches and diversity of data bases offered. Four new retrieval systems were added during the year including the New York Times Information Bank and those provided by the Energy Research and Development Administration. The staff added 25 new literature files to the offerings of the program. Finally, and perhaps most important, more than 1,600 searches were conducted during the year. M.I.T.'s program in this area continues to be one of the best in the country and attracts visitors as well as requests for copies of publications, lectures and demonstrations, and consultation.

Financial

Consonant with the general Institute policy of fiscal restraint, the Libraries' budget for 1976-77 was virtually unchanged, except for salary increases, from the previous year. Reductions of approximately \$60,000 in the budget base were offset by adjustments of some \$65,000 for inflation in materials and supplies. The net effects of these changes, however, were not insubstantial. Two positions, one in the Catalogue Department and the other in the systems area, were dropped along with the replacement of contracted security services by library personnel. Of these decisions, the first has the most immediate impact, that is, delaying the complete processing of materials required by the user community. Other reductions in the budget occurred in the area of duplicate subscriptions and less frequently used serial titles. It is clear that the reductions implemented for the current year have exhausted all available possibilities and if future limitations must be imposed, there will be a serious and dramatic effect on both collections and services.

After three successive years of negative or zero budget growth it is most gratifying to report that the budget for the Libraries for 1977-78 will not call for further reductions but rather includes funds sufficient for anticipated inflation in materials, services, and supplies as well as a modest amount of money to support new research and teaching programs. Completion of the Collection Analysis Project should enable the Libraries to make maximum use of the fiscal resources available.

Archives

With the appointment of a full-time Institute Archivist, Helen W. Slotkin, the Libraries are embarking on a major program of identifying, acquiring, cataloguing, and maintaining a greatly expanded collection of official Institute records as well as documentary evidence of the development of 19th- and 20th-century science and technology. The immediate goals are to gather and train a staff and to establish policies and procedures. The staff will then begin an inventory of existing collections and will begin contacting the various Institute offices and departments to provide advice and assistance on the creation, retention, disposition, and transfer of records. Concomitant with that endeavor will be a program of increasing the collection of faculty papers. As a first step, the Institute Archivist has initiated contacts with Institute Professors, Institute Professors Emeriti, and the M.I.T. members of the National Academy of Sciences, the latter group in cooperation with the American Institute of Physics. A third major effort is in conjunction with the M.I.T. Oral History Program. The Libraries have assumed responsibility for organizing and servicing the collections of transcripts and related background material generated by recombinant DNA research, the work of women in science and engineering, development of the Physical Sciences Study Committee, and oral history interviews with distinguished M.I.T. faculty.

The Institute Archivist, in addition to her primary responsibilities outlined above, has been asked to direct the Libraries' activities of materials conservation and preservation. The general state of many older collections has been a matter of serious concern for many years; several recent incidents of water leaks have served to accentuate the need for a long-range policy in this area. As a first step, a comprehensive survey is being undertaken during summer, 1977 in order to identify the most pressing needs for book preservation and conservation.

Space

While no final decision was reached as to the location of the Libraries' proposed remote storage facility, several discussions were held during the year, and proposals were prepared

Libraries

in response to requests from the Institute's planning staff. The Corporation Visiting Committee for the Libraries, at its April meeting, participated in an extensive discussion of this matter and endorsed the proposed solution by the Director of Libraries of local storage for less frequently used materials. The likelihood of identifying a building for this purpose seems excellent at this time; such a decision can come none too soon because the space situation in most of the M. I. T. Libraries has reached a critical point. The other critical space problems -- in the Rotch and Music Libraries -- do not seem immediately soluble, but efforts are continuing in both of these situations.

OTHER ACTIVITIES

The Libraries prepared several proposals for outside funding during the year. One, the Collection Analysis Project, supported by the Mellon Foundation through the Association of Research Libraries, was approved as described above. A second proposal was prepared jointly with the Harvard-M. I. T. Program in Health Sciences and Technology; it included support for acquisitions and staff in the fields of experimental medicine, biology, biomedical engineering, health economics, and health facilities planning. The Libraries also submitted a proposal to the Center for Research on Women at Wellesley College, for support of a staff member to develop further the collections on women's and men's studies in the Humanities Library. Still in preparation is a proposal for a media facility that would provide for the collecting, cataloguing, and use of video, audio, and film materials.

The Libraries participated extensively in the Independent Activities Period. Of chief importance were the first M. I. T. College Bowl and the second Book Collecting Contest, both of which attracted considerable attention and participation. Other activities included exhibits, a film series, NASIC demonstrations, and a plant cuttings exchange.

The Microreproduction Laboratory effected two major changes: all coin-operated photocopy machines were replaced, resulting in a much higher level of reliability; and a Xerox 4000 copier was installed in the Hayden building to permit self-service copying chargeable to Institute accounts.

The Library Systems Designer, in addition to working closely with all units of the system, spent a great deal of time investigating two potential areas for automation: circulation and acquisitions/accounting.

GIFTS

The M. I. T. Libraries continue to be indebted to a large number of individuals and organizations who have donated materials to the collections. A list of individual donors appears in the archival copy of this report. Among the materials received this year were collections on market research from the Axiom Market Research Bureau and from Stanley Klein, Class of 1958; a facsimile of the Caxton Ovid, given by the Power Foundation; planning reports and correspondence of the late Paul Oppermann given by Mr. and Mrs. Oppermann as decided before his death; a collection of early 20th-century physics treatises from the library of James Franck, donated by Dr. and Mrs. Hermann Lisco; materials relating to M. I. T.'s third president, Francis Amasa Walker, given by J. S. Brittain Walker; two early works on optics and microscopy for the Rare Books Collection from I. Austin Kelly III, Curator of Rare Books in the M. I. T. Libraries and member of the Class of 1926. The acquisition

program benefited from gifts through the Alumni Fund including matching funds from M.I.T. Challenge '77 and from other sources.

It has obviously not been possible to cover all of the activities and accomplishments of the Libraries and the staff in this report. Detailed reports of all departments are maintained in the Office of the Director of Libraries and are available there for consultation.

It is a great pleasure to acknowledge the support and assistance the Libraries have had from the Faculty Committee on the Library System, from the Corporation Visiting Committee for the Libraries, from the faculty, students, and staff of the Institute, and most especially from the Institute administration.

Staff Activities

Emily Blum participated in "Introduction to Administrative Procedures at M.I.T." Sheelah Britt was a member of the M.I.T. Working Group on Office/Clerical Issues. Laura B. Carchia was a member of the Committee on University Industrial Relations Librarians.

Marjorie Chryssostomidis was US representative for the Newsletter of the Marine Librarians Association. She was awarded a contract from the Sea Grant Program for June 1 to December 31, 1977, to prepare a bibliography on offshore oil engineering.

Katharine G. Cipolla published a note on library instruction in the Journal of Academic Librarianship, volume 3, number 1, 1977. With Carole Schildhauer she produced a videotape, "Searching Through Patent Literature," and presented the tape and discussed bibliographic instruction at a Simmons College Graduate School of Library Science class and at the June meeting of the Special Libraries Association (SLA). She gave a point-of-use presentation at Brown University for Providence area librarians.

Clementine I. Coblyn was a member of the Boston Library Consortium Readers' Services Committee. She chaired the Libraries' Circulation Committee.

Jacqueline Z. Colby taught cataloguing and classification at a Library Training Institute of the New England Regional Medical Library Service (NERMLS)/Countway Library of Medicine. She gave two lectures on cataloguing at Simmons College. She was member-at-large of the Executive Committee of the Resources and Technical Services Division (RTSD) Cataloguing and Classification Section (CCS) of the American Library Association (ALA). She participated in M.I.T. Administrative Development Program (A.D.P.) VII.

Betty-Ann Curtis was appointed a permanent member of M.I.T.'s Employee Assistance Planning Group. She served as a permanent member of the M.I.T. Women's Forum Steering Committee.

Margaret E. DePopolo served on the School Council of the M.I.T. School of Architecture and Planning. She participated in the Council of Planning Librarians Journal Citation Study.

Florence K. Doksansky was a member of the M.I.T. Working Group on Office/Clerical Issues. She served as an advisor to new A.D.P. participants.

William J. Duggan served on the Finance Committee of the New England Library Information Network (NELINET).

David S. Ferriero was a member of the NELINET Committee on Interlibrary Communication. He was chairman of the Boston Library Consortium Readers' Services Committee. He was

Libraries

vice-chairman of the Local Arrangements Committee for the Association of College and Research Libraries (ACRL) 1978 National Conference. He was a panelist on the "Future of the Profession" program of the New England Library Association 1976 Annual Conference.

Fae K. Hamilton was a contributing book reviewer to Library Journal.

Kate S. Herzog was a member of the Board of Trustees and of the Executive, Personnel, and Kindergarten Planning Committees of M.I.T.'s Technology Children's Center. She participated in M.I.T.'s A.D.P. VIII.

Irma Y. Johnson was vice president of the New England Chapter of ACRL. She served on the ACRL Bibliographic Instruction Committee. She chaired the Planning Committee for the ACRL New England meeting on microforms held in April at M.I.T. She was deputy chairman of the Program Committee for the ACRL 1978 National Conference. She was a panel member at a March meeting of the Standing Committee on Professional Development of the Harvard University Librarians Assembly.

Eileen Kibrick participated in A.D.P. IX.

James M. Kyed was chairman of the Membership Committee of the American Society for Engineering Education (ASEE) and served on the ASEE Arrangements Committee. He edited Scientific, Engineering and Medical Societies: Publications in Print, 1976-1977 (James Matarazzo, co-editor), published by R. R. Bowker Company in September. His review of Ellis Mount's book University Science and Engineering Libraries: Their Operation, Collections, and Facilities, was published in the November 1976, issue of Special Libraries.

Aleksander Leyfell was Honorary Research Fellow of the Harvard University Russian Research Center.

David D. Lewallen served as chairman of the Independent Activities Period Committee of the Libraries.

Leonore K. Linsky was M.I.T. Community Service Fund solicitor for the Libraries.

Ann S. Longfellow served on the Nominating Committee of the SLA Boston Chapter.

Jay K. Lucker was a member of the M.I.T. Cable Television Policy Board. He was treasurer of the M.I.T. Chapter of Phi Beta Kappa. He served as an M.I.T. freshman advisor. He was a guest member of the M.I.T. Press editorial board. He was a member of the Ad Hoc Personnel Committee for the M.I.T. Writing Program. He served as a member of the Board of Directors of the Boston Library Consortium and of the Board of Directors of the New England Deposit Library. He continued as chairman of the Association of Research Libraries (ARL) Interlibrary Loan Committee. He was a member of the ALA Interlibrary Loan Committee and delivered at the ALA midwinter meeting a paper on the ARL survey on interlibrary loan charges. He served as chairman of the Middle States Association of Colleges and Secondary Schools Commission on Higher Education accreditation team that visited Skidmore College in April. He was a contributor to American Reference Books Annual, published by Libraries Unlimited, Inc. He presented a seminar at the Carnation Company Research Laboratories in Van Nuys, California, on M.I.T. library services and recent developments in information services.

Sylvia A. McDowell was United Way Campaign solicitor for the Libraries. She served as an M.I.T. freshman advisor. She developed a procedure for organizing the pamphlet collection of the Institute for Responsive Education of Boston University.

Suanne W. Muehlner served on the Classification Review Committee of M. I. T.'s Salary Administration Program. She was a member of the M. I. T. Working Group on Office/ Clerical Issues. She was a member of the ALA Library Administration Division (LAD) Personnel Administration Section Economic Status, Welfare, and Fringe Benefits Committee. She was a member of the ALA RTSD Reproduction of Library Materials Section Telefacsimile Committee. She was elected vice president of the Governing Board of the Alumni Association of Simmons College Graduate School of Library Science.

Frances R. L. Needleman was a member of the ALA RTSD Committee on Computer Filing. She was a speaker at the RTSD CCS Subject Analysis Committee meeting. She served on the Boston Library Consortium Cataloguing Committee.

Susan K. Nutter was treasurer of the New England Chapter of the American Society for Information Science (ASIS). She was a member of the Advisory Committee for Microform Proposals of the NELINET Government Documents Task Force. She was a panelist at the NELINET Government Publications in Microform Workshop held in Boston in January.

Margaret A. Otto served on the Classification Review Committee of M. I. T.'s Salary Administration Program. She was a member of the Executive and Nominating Committees of the ALA LAD Library Organization and Management Section. She was a member of the NELINET Executive Committee and Search Committee for director of NELINET. She served on the Executive Board of the Universal Serials and Book Exchange, Inc.

Mary E. Pensyl served on the Committee on the Selection of Data Bases of Bibliographic Retrieval Services. Her paper "Patterns of Growth in a University's Fee-for-Service On-line Search Center," written with Susan Woodford, was accepted for publication in the 1977 Proceedings of the ASIS Annual Meeting. With Woodford she wrote "Continuing User Education to Promote the Effective Use of an Established Search Service in a University Community." She gave eight talks on computerized bibliographic services: "Engineering Data Bases: Anatomy of Searching," at the fourth Annual Dialog Users' Conference in May; a talk on health-related data bases at a NERMLS workshop in April, with Woodford; "Introduction to Computer Searching: What It Is, How to Do It, How to Start a Search Service," at the April meeting of the SLA Upper New York Chapter meeting at the University of Rochester; seminars in April and December for a Simmons College course in science and technology, with Woodford; "Centralized On-line Searching," at a NASIC Users' Conference held in March at Boston College; "The Administrative Dilemma: The Library and Data Bank Services," at a seminar on bibliographic data bases sponsored in June by the Midwest Regional Library Network; "The Role of On-line Searching in the Library Environment," at the ASEE meeting in June in Knoxville, Tennessee.

Jutta R. Reed served on the planning committee of the ACRL New England meeting on microforms held in April at M. I. T. and at that meeting presented a paper on microform collection development. She chaired the Libraries' committee on M. I. T. Reports. She was a member of the Boston Library Consortium Selection/Acquisitions Committee. She published "Cost Comparison of Periodicals in Hard Copy and on Microform" in the July, 1976, issue of Microform Review and "A Book Review: Microform, the Librarians' View, 1976-77, by Paula Dranov," in the January/February, 1977 issue of the Journal of Micrographics.

Carole Schildhauer published "The 4-Day Work Week, the M. I. T. Experience" in the October/November, 1976 issue of the SLA Boston Chapter News Bulletin. With Katharine Cipolla she produced a videotape, "Searching Through Patent Literature," and presented the tape and discussed bibliographic instruction at a Simmons College class and at the June meeting of SLA.

Libraries

Nancy C. Schrock wrote the introduction and prepared the bibliography and index to a 1976 reprint of William James Linton's 1881 publication The History of Wood Engraving in America.

Peter R. Scott was a member of the National Micrographics Association (NMA) Microfiche Standards Committee and a member of the NMA Company of Fellows. He served on the American National Standards Institute Committee PH5 on Documentary Reproduction.

Patricia M. Sheehan was chairman of the New England Chapter of ASIS. She was a representative of the Library Automation Special Interest Group of the National Assembly Cabinet of ASIS. She reviewed the ASIS "National Data Base for Audio-Visual Resources." She was visiting lecturer and an Alumni Day Speaker at Simmons College. She was a member of the Ad Hoc Serials Group. She served on the Governor's Committee of the White House Conference on Libraries and Information Science, on the Governor's Omnibus Committee for the Study of Massachusetts Laws Relating to Libraries, and on the Governor's Task Force for Massachusetts Long-Range Program for Library Development. She was a member of the Library of Congress Communications Hardware Panel. She was local arrangements chairman and panel member for a BIOSIS seminar in Boston. She participated in an EDUCOM study on library networks. She was a member of the Boston Library Consortium Serials Committee. She served as the Libraries' liaison with NELINET.

Helen W. Slotkin was a member of the Society of American Archivist College and University Archives Committee and of the Subcommittees on the Buckley Amendment and on the College and University Archives Directory.

Linda I. Solow served on the Board of Directors and the Publications Committee of the Music Library Association (MLA). She was program coordinator and member of the Planning Committee for the MLA 1978 Conference. She served on the Commissions on Professional Training and on Bibliographic Description of the International Association of Music Librarians (IAML). She presented a paper, "Education for Music Librarianship in the United States," at the IAML conference in Bergen, Norway, in August. Her "Index to Publishers, Engravers, and Lithographers and a Bibliography of Sources Cited in the IAML Guide for Dating Early Music" was published in the April 1977 issue of Fontes artis musicae.

Catherine M. Stevens participated in "Introduction to Administrative Procedures at M. I. T."

Jacqueline Stymfal was a member of the NELINET Government Documents Task Group. She was a reviewer for a proposed government documents series to be published by R. R. Bowker Company. She participated in M. I. T. Administrative Development Program VIII.

Theresa A. Tobin was a member of the M. I. T. Working Group on Office/ Clerical Issues.

Marilyn G. Walker participated in M. I. T. 's Administrative Development Program IX.

Susan Woodford, with Mary Pensyl as co-author, wrote the paper "Continuing User Education to Promote the Effective Use of an Established Search Service in a University Community." She was co-author with Ms. Pensyl of "Patterns of Growth in a University's Fee-for-Service on-line Search Center, which was accepted for publication in the 1977 Proceedings of the ASIS Annual Meeting. She gave two talks in April with Ms. Pensyl on computerized bibliographic service, one at a NERMLS workshop on health-related data bases, the other at a seminar for a Simmons College course in science and technology.

Ellen Yen participated in M. I. T. Administrative Development Program VIII.

Staff Changes

The following new appointments were made this year: Fae K. Hamilton, Head, LC Cataloguing Section; Helen W. Slotkin, Institute Archivist; Sandra E. Spurlock, Assistant Science Librarian; and Nancy R. Whitman, Assistant Science Librarian for the Department of Transportation.

The following promotions and transfers took place: Lois M. Chalmers, Serials Cataloguer; Richard M. Fletcher, Assistant Humanities Librarian; and Suanne W. Muehlner, Assistant Director for Public Services.

The following retired from the Libraries staff: Eleanor L. Bartlett, Archives Librarian; Barbara C. Darling, Aeronautics and Astronautics Librarian; and Frances B. B. Sumner, Humanities Librarian.

Resignations this year included: E. Neal Hartley, Institute Archivist; Ann S. Longfellow, Assistant Rotch Librarian for Reference; Divina M. Lynch, Department of Transportation Librarian; and Pamela G. Reekes, Head, LC Cataloguing Section.

JAY K. LUCKER

Lowell Institute School (L.I.S.)

The Lowell Institute School was established at M.I.T. in 1903 to provide evening instruction in technical subjects for residents of the Boston area. Today the School continues this tradition by offering subjects in the areas of modern technology which are not readily available at other evening institutions. The general level of instruction is geared to the practicing technician who has an Associate's degree or equivalent experience.

The programs of study range from single subjects designed to broaden an individual's skill level in his or her present job, to comprehensive study of new technological areas which will prepare a technician for employment in a new field. There is a strong emphasis on practical aspects and development of careful experimental technique, combined with sufficient theory to provide an adequate foundation of understanding. Certificates are awarded to those who complete a satisfactory program.

During 1976-77, L.I.S. added to the existing curriculum new courses in Applied Mathematics for Electronics, Improving Oral Communication, Advanced Scientific Glassblowing, Projects in High Speed Photography, Semiconductor Devices, and Introduction to Microprocessors. This latter course proved extremely popular; so much so that an arrangement was made with the Boston Section of the Institute of Electrical and Electronics Engineers (I.E.E.E.) to offer jointly a one-week, intensive microprocessor course as a laboratory oriented follow-up to the I.E.E.E.'s evening lecture series on the subject. Again the demand was so great that a total of six of these one-week courses were given in Cambridge, plus an additional week at the CBS Network in New York City.

Continued in the curriculum were courses in Technical Writing, Creative Photography, Mechanical Drafting, Op-Amp Applications, Digital Electronics, Television Systems, Principles of Metal Joining, and Machine Tool Fundamentals.

The continued increase in electronics courses prompted a return to the offering of a special certificate to those who complete a two-year program in this area. Thus, in addition to the 24 individual course offerings, L.I.S. now has two-year programs in Electronics Technology and in Television Systems Technology.

Enrollment at L.I.S. also continues to climb, with 611 students admitted to the evening classes and 94 students admitted to the intensive, one-week courses. This represents a 30 percent increase over the 1975-76 figure of 542. Of those who enrolled, 81 percent successfully completed the certificate requirements. Among those who completed courses were 36 M.I.T. employees and three regular M.I.T. students. The high completion rate is testimony to the dedicated instructor staff, which consists of M.I.T. faculty and graduate student teaching assistants as well as skilled instructors from the Boston area's industry. The continued increase in enrollment and the high completion rate indicate that both the subjects offered and level of instruction are well-matched to the needs of technician-level personnel.

BRUCE D. WEDLOCK

Northeast Radio Observatory Corporation (NEROC)

Haystack Observatory

M.I.T. is a leading member of NEROC, a consortium of 13 institutions* formed in 1967 to promote radio and radar astronomy research and facilities in the northeastern United States. Through a NEROC-M.I.T. agreement, NEROC uses the administrative services of M.I.T. in the conduct of its business.

The primary current responsibility of NEROC is the operation of the Haystack Observatory, located at the Millstone Hill Field Station of M.I.T. in Westford, Massachusetts. The main instrument at the Observatory is a 120-foot diameter, paraboloidal antenna enclosed in a radome. With support from the National Science Foundation, it is used almost continuously by the astronomy community at-large as a radio telescope covering the wavelength region from 21cm down to 0.7cm. At the latter wavelength the telescope has a beamwidth smaller than the 1-arc-minute resolution of the human eye. Observing proposals submitted by prospective users are considered weekly by a review committee on the basis of scientific merit and suitability for the available instrumentation. In addition to the astronomical observations, a modest fraction of the observing time is scheduled for radar observations of satellites funded by M.I.T. Lincoln Laboratory.

Of the 21 students doing thesis research at Haystack this year, two recently received the Ph.D., while four more will receive the Ph.D. later in 1977. Over 70 scientists representing some 20 institutions used the Haystack telescope for spectrometric and continuum observations in the year just past. This does not include Haystack's role, mentioned below, in multi-telescope very-long-baseline interferometer (VLBI) research.

About 60 percent of the telescope time was used this year for observations of spectral-line radiation from molecules in the interstellar medium and from atoms in ionized regions (recombination radiation). These observations used the 1024-channel autocorrelation spec-

*Boston University, Brandeis University, Brown University, Dartmouth College, Harvard University, M.I.T., Polytechnic Institute of Brooklyn, Smithsonian Astrophysical Observatory, State University of New York (SUNY) at Buffalo, SUNY at Stony Brook, University of Massachusetts, University of New Hampshire, Yale University

trometer, which earlier this year made possible the discovery of evidence for quasi-thermal circumstellar shells in the SiO emission (wavelength = 7mm) from long-period variable stars. A search for recombination-line emission at 4-cm wavelength from external galaxies led to a definite detection in the irregular galaxy M82, 10 million light years distant. Such spectral-line observations at radio wavelengths make it possible to look inside clouds of dust and gas which are impenetrable to visible light.

Observations of continuum radio emission occupying about 20 percent of the observing time, include a long-term monitoring program which follows time variations in the 2- and 4-cm emission from very distant objects, quasars, and peculiar galaxies. Haystack is participating in combined radio-infrared observations with balloon experimenters at the Center for Astrophysics (Harvard-Smithsonian).

Haystack's most noteworthy in-house research contribution has perhaps been in the field of Very-Long-Baseline Interferometry. This technique, which involves simultaneous observations of the same object with widely separated telescopes, has potential for astrometry of unprecedented accuracy, for study of the detailed structure of complex sources at the milliarcsecond level, for "gravitational bending" tests of general relativity, and for precise geodetic measurements of several types. Recently, quasar positions have been determined through VLBI experiments with a scatter between experiments of less than 0.05 arcsec. Observations since 1970 of the quasar 3C 279 show evidence for two compact components whose angular separation, measured in milliarcseconds, is increasing steadily. If indeed 3C 279 lies at the very great distance suggested by its large redshift, then these two components must have an apparent speed of separation of (26 ± 3) times the velocity of light.

An improved system for VLBI data recording and processing, the so-called Mark III System, is under development at Haystack, with support from the National Aeronautics and Space Administration Goddard Space Flight Center. Through greatly increased recorded bandwidth, the Mark III System affords more than a fivefold increase in system sensitivity as compared to the best now available. We expect that this system will be ready for preliminary tests in the fall of 1977.

PAUL SEBRING

Neurosciences Research Program (N.R.P.)

The Neurosciences Research Program is an international, interuniversity, and multidisciplinary organization operating as a research center of M.I.T. Its purpose is to promote progress toward bridging the gaps separating the data and concepts of traditional scientific disciplines engaged in research on the nervous system at various levels of its organization -- molecular, cellular, neurophysiological, and behavioral. Theoretical breakthroughs are essential to transforming new information into scientific understanding of how the nervous system mediates behavior, including the mental life of humans.

There are four main elements in the program: the operation of a worldwide communications exchange between scientists, the organization of scientific collaboration and meetings, a program of publications, and a program in graduate and postdoctoral education.

To carry out these activities, some 36 scientists, leaders in major neuroscientific disciplines, are elected to serve as N.R.P. Associates to provide advice and guidance to a small profes-

sional staff at the N. R. P. Center in Boston. N. R. P. also enlists the participation in its activities of scientists from the neuroscientific community at large; over 1,500 scientists have served as invited consultants.

The following work sessions and/or conferences (chairpersons shown in parentheses) were held during the academic year 1976-77:

"Neurobiology of Peptides" (L. L. Iversen, R. A. Nicoll, and W. Vale); "The Developmental History of the Neuron" (W. M. Cowan and R. K. Hunt); "Neuron-Glia Interactions" (G. G. Somjen and S. S. Varon); "Synapse Formation and the Cell Surface" (G. D. Fischbach and D. I. Gottlieb); and "Sexual Differentiation of the Nervous System" (B. S. McEwen and R. W. Goy).

At the fall (32nd) Stated Meeting of N. R. P. Associates (October 17-20, 1976) five newly elected Associates, Drs. J. P. Changeux, W. M. Cowan, J. E. Dowling, E. V. Evarts, and M. Konishi, gave inaugural lectures describing their major research aims and accomplishments. Also, for half a day, the Associates reviewed the latest plans for the subjects and lecturers scheduled for the Intensive Study Program at Boulder, Colorado, June 20-July 1, 1977.

Another feature of the fall Stated Meeting was the fourth F. O. Schmitt Lecture in Neuroscience, given October 20, 1976, in Kresge Auditorium. The 1976 medalist, Dr. Viktor Hamburger, gave an address entitled "The Developmental History of the Spinal Motor Neuron." This was published as a supplement to the N. R. P. Bulletin.

The spring (33rd) Stated Meeting of N. R. P. Associates was held March 20-23, 1977. Eight new members were elected: Drs. J. Axelrod, T. Hökfelt, P. Greengard, R. D. Keynes, A. M. Liberman, P. Mueller, F. Plum, and S. H. Snyder.

The scientific program was vigorously discussed, and included three special topics: 1) "Problems for Neurobehavioral Research," chaired by D. Ploog, with talks by H. F. R. Prechtl, A. L. Liberman, A. Cowey, N. E. Spear, and R. Crowder; 2) "Enzyme Cascades as Amplifying Devices in Neurophysiological Transductive Coupling," chaired by D. E. Koshland, with H. J. Müller-Eberhard, L. J. Reed, and E. R. Stadtman; and 3) "Transmitters as Neurohumors for Modulation in the Nervous System," chaired by S. S. Kety, with S. L. Palay, V. Chan-Palay, and R. Y. Moore. A number of individual talks by Associates were also included in the scientific program.

Dr. Roger Guillemin was selected to receive the 1977 F. O. Schmitt Award in Neuroscience, and to deliver the fifth F. O. Schmitt Lecture, October 5, 1977.

During the academic year 1976-77, the following N. R. P. Bulletins were published: "Neuro-anatomical Functional Mapping by the Radioactive 2-Deoxy-D-Glucose Method" (F. Plum, A. Gjedde, and F. E. Samson); "Brain Interactions With Weak Electric and Magnetic Fields" (W. R. Adey and S. M. Bawin); "Neuronal and Neurochemical Substrates of Reinforcement" (J. Olds, F. E. Bloom, and R. D. Hall); and "The Developmental History of the Spinal Motor Neuron" (V. Hamburger, F. O. Schmitt Lecture).

To reduce costs, and to achieve a more professional marketing, a contract with the M. I. T. Press effective January 1, 1977, provides that the N. R. P. Bulletin will be published, printed, and distributed by the M. I. T. Press. N. R. P. retains editorial control, and submits manuscripts in typewritten rather than camera-ready form.

Over the last three years the Associates and staff of N. R. P. have followed with keen interest certain new notions of the way neurons interact with each other and conduct their internal

metabolic and bioelectric affairs. The new look was articulated by F. O. Schmitt in his National Lecture to the Biophysical Society in 1975 and in a paper with Drs. P. Dev and B. H. Smith which appeared in a recent issue of Science (July 9, 1976, Volume 193). This publication has evoked much interest and correspondence with neuroscientists around the world. To bring this crucial development most forcibly before the scientific community, a two-week Intensive Study Program (ISP) has been organized for June 20 to July 1, 1977, at Boulder, Colorado. Some 80 neuroscientists and 50 very carefully selected postdoctoral fellows will participate. The proceedings will be published in a large volume, the fourth in the series, to be entitled "The Neurosciences: Fourth Study Program." It is hoped that this ISP, through its effect on the young postdoctoral fellows and through the book, will implement the quiet revolution that has for several years been gathering momentum, and will cause the neuroscience community to pursue a new course in its attempt to understand the physical, chemical, and neuronal bases of higher brain function.

Planning of the scientific program is now completed, and 50 ISP Fellowships have been awarded after a highly competitive selection procedure that evaluated almost 200 outstanding candidates nominated by leading neuroscientists from the United States and abroad.

Although the thrust of the 1977 ISP is at the basic level, it is reasonable to hope that these discoveries, data, and concepts will lead neuroscience research toward new understanding of how physical processes in the nervous system are linked to psychological phenomena such as perception, learning, memory, and emotion in normal and clinically disordered humans.

The M.I.T. graduate seminar 20.515 Seminar in Neuroscience Research Topics continues to attract selected graduate students from M.I.T., Harvard, and other Boston-area institutions. Students attend N.R.P. work sessions, Stated Meetings, and conferences, are required to take notes during work sessions, and to participate in a review of the work session with N.R.P. staff and work session chairmen. Each student prepares a written proposal, defining a research topic in neuroscience.

F. G. WORDEN

Operations Research Center

The Operations Research Center conducts interdepartmental academic and research programs in operations research. The academic staff of the Center is drawn from many departments, including the Sloan School of Management, Urban Studies and Planning, Electrical Engineering and Computer Science, Aeronautics and Astronautics, and Physics. At present, approximately 18 students are in the operations research doctoral program and a comparable number are in the master's program. Most of them come to M.I.T. specifically to study operations research and are admitted directly by the Center, although some learn about the graduate operations research programs by attending seminars or subjects.

During the past year, the academic staff of the Center has engaged in a wide range of research activities sponsored directly by the Center. There was basic research into the methodologies underlying operations research including mathematical programming, decision analysis, and probabilistic models. There was also a variety of model building and applications oriented research using these methodologies.

Basic research into the mathematics of operations research received continued strong attention. Developments included further work on integer programming duality theory, arising from the implementation of the theory and its use on a variety of integer programming problems. Additional basic research in discrete optimization and network optimization was performed. Research was completed on the modeling and analysis of decision problems where alternatives have consequences to each of a collection of individuals or interest groups. Research in robust estimation and the sensitivity analysis of econometric models was continued.

An applied research project studying public attitudes and decision processes with regard to blood donation entered its final year. The work concentrated on issues such as the effects of the collecting organization's ideology on donor selection and on donor's "reasons" for giving, the spread of donor activity and blood knowledge in the population, and the circumstances under which donors become exdonors. Findings are that the blood supply and the willingness of the public to participate in it are much better than is generally assumed.

A one-year project to evaluate the consumer's interest in automobile insurance merit-rating plans was carried out during 1976-77. Merit-rating plans were analyzed in order to recommend minimum standards for such plans, to estimate the impact that such plans might have on the total cost of insurance premiums and the distribution of these costs among Massachusetts motorists, to determine data requirements for evaluating the effectiveness of such plans, and to identify conditions under which "merit rating" is a desirable means of distributing accident costs.

Joint applied research with the Center for Transportation Studies entered its second year. Results included extensions of the uni-modal traffic equilibrium model to the multi-modal case, including generalizations of demand functions for traffic flow, new existence theorems about equilibria, and algorithms for solving the multi-modal problem. Other research performed on this project was directed at problems of train operations including a study of train formations and work allocations among train years. Finally, there was continuing work on algorithms for network design and location problems.

A long-term project on multi-level logistics systems received continued support and attention. Decomposition methods were devised and tested to partition, link, aggregate and disaggregate large-scale production, inventory, and distribution systems. Applications were made to several industrial production planning problems.

Modeling and analysis of urban vehicular services also continued during the past year. There were extensions and new implementations of the hypercube queuing model for facility location and redistricting in urban emergency services. Other research included: random walk models of servers in emergency vehicles, quantitative models for describing and controlling clumping in buses, an optimal delay study of transit vehicles at transfer points, network analysis and Markovian decision models for the dynamic relocation of mobile servers. In addition, research was begun in the new area of quantitative techniques for the evaluation of public programs.

An important new area of theoretical and applied research during the past year has been in the use of operations research models and methods in economic planning problems. Basic research was completed on the mathematical structure and solution of economic equilibrium problems arising in energy and traffic modeling. Collaborative research was begun with Brookhaven National Laboratory on the extension and analysis of the Brookhaven Energy System Optimization Model, which is a linear programming representation of the US energy sector in selected years in the future. A simplified version of this model was used in a separate study of the optimal use of depletable resources. Other economic planning problems, studied during the past year, included the determination of government subsidies for economically depressed areas and optimization models for planning economic development.

Operations Research Center staff and students were involved in a variety of research activities with other departments and centers both within and outside M.I.T. For example, several students and staff were involved in a study at the M.I.T. Energy Laboratory of the effectiveness of technical and institutional research and development initiatives in improving light water moderated nuclear reactors. Research continued at the Energy Laboratory on a probabilistic model of the oil and gas exploration process that constitutes a component of an economic supply function for petroleum reserves from new discoveries. Staff and students were also involved in traffic studies at the Electronic Systems Laboratory and in an earthquake study in the Department of Civil Engineering.

Several members of the Operations Research Center staff were active in research programs at the National Bureau of Economic Research Computer Research Center for Economics and Management Science located in Cambridge. Their activities included development of interactive computer systems for linear and integer programming and methods of robust estimation. The computer tools developed at the Computer Research Center are publicly available and have been used on many applications of the research projects mentioned previously.

Support for the Center's research during the past year has come from the Army Research Office, the Public Health Service, the Massachusetts Automobile Rating and Accident Prevention Bureau, the US Department of Transportation, and the Office of Naval Research.

JEREMY F. SHAPIRO

R.O.T.C. Programs

Because of rapidly increasing R.O.T.C. enrollments, the issue of unit viability now at last seems to be behind us. For the past several years there has been a concern that one or more of the services would be forced to disestablish their R.O.T.C. unit at the Institute due to a failure of the unit to meet minimum enrollment standards. The increased enrollments are the result of the expansion of R.O.T.C. scholarship programs and the establishment of cross-enrollment arrangements with neighboring universities. Cross-enrollment for R.O.T.C. is permitted for Wellesley and Harvard students through regular academic exchanges and for Tufts and Northeastern students through special limited exchange agreements. Over three hundred students are now participating in R.O.T.C. at M.I.T., more than twice the number enrolled in 1973-74.

The success of M.I.T. students in the national competition for R.O.T.C. scholarships is especially gratifying. While less than half of the R.O.T.C. students nationally are scholarship recipients, more than three-quarters of M.I.T.'s R.O.T.C. students are scholarship holders. These scholarships provide full tuition plus a monthly stipend for up to four years.

Attention this year has focused on a review of the R.O.T.C. curriculum, the first such review undertaken by the committee in seven years. The specific issue being addressed is whether or not full academic credit shall be awarded for subjects taught by R.O.T.C. instructors.

The committee has sought to employ a variety of methodologies in its review of the R.O.T.C. curriculum. The historical record was examined, syllabi were analyzed, instructors and students were surveyed, discussions with faculty members and department heads were held,

Sea Grant Program

and the practices of other universities were reviewed. The committee's report is due next year.

HARVEY M. SAPOLSKY

Sea Grant Program

During the academic year 1976-77, M.I.T. became the first private university to be designated a Sea Grant College and the twelfth institution to be so recognized for its excellence in marine research, education, and advisory services. The Sea Grant Program of M.I.T. accepted the honor as a challenge to strengthen its commitment to help the citizens of Massachusetts, New England, and the nation supply needed marine resources through thoughtful development of the ocean.

In its fifth year as a Sea Grant institution, M.I.T.'s Program received increased Federal funding through a grant of \$1,236,800 from the office of Sea Grant, a division of the National Oceanic and Atmospheric Administration (NOAA) in the US Department of Commerce. Matching funds of \$664,700 made up well over the required one-third of the total Program funding of \$1,901,500.

These matching funds came from the Institute itself, from the Henry L. and Grace Doherty Charitable Foundation, Inc., the University of Massachusetts, the Massachusetts Maritime Academy, International Copper Research Association, Fugro Geotechnical Consultants of Holland, the fishing industry of the Commonwealth, and from other organizations and institutions from the United States and abroad.

Dean A. Horn led the M.I.T. Sea Grant Program as Director while maintaining his position on the Institute faculty as Senior Lecturer in the Department of Ocean Engineering. The Sea Grant management reorganization plan, outlined last year, was completed in September with the appointment of Professor Jerome J. Connor, Jr., (Civil Engineering) as Director of Sea Grant Research. Professor Connor is responsible for defining and developing the themes and objectives for Sea Grant research. Ernest R. Pariser was designated Associate Director for Advisory Services. Mr. Pariser is also Senior Research Scientist in the Department of Nutrition and Food Science. The Program's daily operations were managed by James E. Grayson, Administrative Officer, through June 30, 1977. Lawrence W. McKinnon took his place when Mr. Grayson moved to a new position within the Institute.

The M.I.T. Sea Grant staff, seeking to refine the goals and activities of the Advisory Services, met frequently with representatives from government and industry through the Sea Grant State-Industry Advisory Council. The collaboration produced a more efficient and effective transfer of information to the Program's constituents in the Commonwealth, the New England region, and the nation.

The Sea Grant Policy Committee and the Sea Grant Faculty Council, chaired by Dean Alfred A.H. Keil of the School of Engineering, counseled the Program staff in its efforts to synthesize marine research with the marine education of future scientists, engineers, and teachers.

An important event in 1976-77 for Sea Grant and M.I.T. was the completed conversion of an Army-T Boat into the Research Vessel EDGERTON, under the supervision of Arthur B. Clifton, Marine Liaison Officer.

ADVISORY SERVICES

The Sea Grant Program's Advisory Services continued during 1976-77 to improve the substance and efficiency of its assistance to its major constituencies: the industries that apply new technologies to business opportunities in the oceans; and the marine communities and governments concerned with utilizing the rich resources of the ocean while achieving environmental and social harmony on the coastlines. Drawing upon Sea Grant's well established research and educational components, and upon the Institute's expertise and capabilities, the Program has been notably successful in providing advisory information to each of these user groups.

Dr. J.H. Hollomon of the M.I.T. Center for Policy Alternatives was commissioned by the Office of Sea Grant, NOAA, to assess the commercial impact of past Sea Grant sponsored projects. The study was instigated to provide management with an analytical method for choosing future projects which would be profitable for the users; the results affirmed the effectiveness of the existing unique combination of research, education, and advisory services in achieving this goal.

The M.I.T. Marine Industry Advisory Service, (MIDAS) continues to evolve under the direction of Norman A. Doelling. The Collegium, established in April 1975 as a component of MIDAS, enrolled 84 companies of national and international stature during 1976-77. Through the Collegium, the users, marine oriented industries, and M.I.T. researchers worked to define profitable new opportunities in the seas. Four Opportunity Briefs, produced for and distributed to Collegium members last year, described the technical and market potential of electron irradiation of sewage sludge, closed-cycle aquaculture, the problems and opportunities of oil spills, and computer modeling for environmental engineering near the coasts.

The Marine Industries Business Strategy Program (Maribus), also a part of MIDAS, sponsors an intensive, in-depth study of a selected marine resource, product, or service that is particularly interesting and potentially profitable. In 1976-77, M.I.T.'s Center for Policy Alternatives addressed the industrial prospects for the utilization of chitin and its derivatives. The Maribus report recommended a strategy to both suppliers and users of chitin, resolving their respective problems with one solution.

Because of intense interest by industry and science in chitin, the M.I.T. Sea Grant Advisory Services, in cooperation with the Massachusetts Science and Technology Foundation, and the Sea Grant Programs of the University of Delaware and the University of Washington, sponsored the First International Conference on Chitin and Chitosan in April 1977.

Papers describing both theoretical and applied research were delivered to 91 conferees from the United States and 13 foreign countries.

The M.I.T. Sea Grant Program joined with the University of Massachusetts in July 1976 to establish a marine extension advisory service for the freer transfer of Sea Grant research results to the citizens of the Commonwealth. Mr. Pariser directed the extension education programs which were intended to resolve marine related problems, provide opportunities for wise use of the ocean's resources, and assist in the implementation of proper management of existing resources.

The Sea Grant Program is also an active participant in the New England Marine Advisory Service (NEMAS), a consortium of the region's Sea Grant schools and marine oriented institutions. NEMAS responds to regional needs for information pertinent to ocean and coastal zone activities. Mr. Pariser, who served as vice chairman of the NEMAS board of directors for 1976-77, was elected chairman of the board for 1977-78.

The Sea Grant Program maintained its advisory links with the state government over the past year. Professor John W. Devaney III of the Department of Ocean Engineering was the Program's representative on the Governor's Task Force on Coastal Resources, a citizen's group appointed to assist the Commonwealth's Office of Coastal Zone Management in policy matters. Bronwyn Hurd, the Sea Grant Editor, served on the Task Force's Public Participation Committee. Mr. Clifton worked with the Lieutenant Governor's Massachusetts 200-Mile Work Group that advised the Commonwealth on the newly extended jurisdiction. In cooperation with Sea Grant marine extension advisors, the Conservation Commissions of Dennis and Eastham, and the Barnstable District Conservation Commission, under the guidance of Professor Connor, have installed an experimental perched beach composed of sandfilled plastic bags in Dennis and Eastham for the rebuilding of eroded beaches on Cape Cod.

The highlight of Sea Grant Advisory Services symposia for 1976-77 was the Fifth Annual Sea Grant Lecture in September. Dean Keil delivered the lecture, "The United States and the Oceans: Opportunities for Independence." Panelists responding were Dr. Hollomon; Dr. G.F. Mechlin, Vice President of Research and Development, Westinghouse Corporation; and Marvin Pitkin, Assistant Administrator for Commercial Development, US Maritime Administration. Mr. Horn was moderator.

ACADEMIC PROGRAM

The M.I.T. Sea Grant Program sponsors marine education as a vehicle for training those who can put new technologies to work in the seas. The Program supports expansion of the Institute's ocean oriented curriculum, and provides opportunities for the practical application of students' classroom knowledge to marine and coastal zone problems.

The Department of Ocean Engineering offered four new subjects during academic year 1976-77: Boundary Layers; Free Surface Hydrodynamics; Offshore Engineering Design; and Introduction to Random Processes in the Ocean. Supported by Sea Grant, professors in the Department are preparing a textbook for advanced undergraduates on random processes in ocean engineering. Sea Grant cooperated with the Office of Summer Session in 1976 in presenting four week-long subjects to practicing professionals from industry, government, and education. The topics were: Risk and Decision in Geotechnical Engineering; Coastal Wave Hydrodynamics -- Theory and Engineering Applications; Reliability of Welded Structures; and Ocean Resources Management: Legal and Policy Aspects.

In marine related education and training, the Sea Grant Program involves students in practical, interdisciplinary studies of ocean engineering and coastal zone planning. Undergraduate and graduate students in the summer laboratory, led by Professor A. Douglas Carmichael of the Department of Ocean Engineering, successfully installed a side scan sonar in the free-swimming robot submersible being refined by the students to provide sophisticated oceanographic data from deep water. Reports on a small wind and tidal powered electrical generating device and a method to measure and test breakwater efficiency were completed in 1976-77.

Awareness of serious problems of unplanned land use have prompted several Massachusetts communities to seek help from the interdisciplinary systems design subject students of Professor William W. Seifert of the Department of Civil Engineering. Previous studies, sponsored by Sea Grant, of Gloucester and Boston's South Shore were followed in 1976-77 by an analysis of the harbor area in Lynn. Technical, economic, and legal recommendations for the redevelopment of the area were presented in a public hearing in May 1977. The Lynn City Council officially accepted the plan by vote in June 1977.

In the spring of 1976, M.I.T. Sea Grant, represented by Mr. Clifton, began a cooperative effort with the Massachusetts Maritime Academy to establish a commercial fisheries training program through the development of a fisheries curriculum elective for cadets.

RESEARCH

Through the research projects it supports, the M.I.T. Sea Grant Program seeks to increase society's use of marine resources, and to bring together Institute departments and disciplines that can pursue promising opportunities and solve problems in the ocean and the coastal zones.

New technology for offshore structures will provide the means of advancing human activities in the seas. Several Sea Grant projects are seeking to ensure the strength and stability of platforms on which the work will be done. Using existing Dutch cone penetration data, Professors Mohsen M. Baligh and Charles C. Ladd of the Department of Civil Engineering are developing a procedure to test marine soil properties simply, accurately, and consistently for use in determining site suitability. Professor J. Kim Vandiver of the Department of Ocean Engineering is continuing work on a novel analytic method. He is investigating the use of nondestructive techniques to determine the integrity of offshore structures subject to random wave action. Professor Vandiver is the second Henry L. Doherty Assistant Professor in Ocean Utilization, a chair established through the generosity of Henry L. and Grace Doherty Charitable Foundation, Inc., and administered through the M.I.T. Sea Grant Program.

The Program, following Institute tradition, works closely with industries to define and resolve existing problems. In a marine environment, most common metallic and natural fibers degrade. Professors Richard D. Donnelly and Robert E. Cohen of the Department of Chemical Engineering are working to modify the surface of common polymers to enhance their performance as underwater electrical cable insulation. Professor Koichi Masubuchi of the Department of Ocean Engineering completed the second of three phases of a research project to design new improved underwater welding and cutting techniques. The unique stud-welding gun and the underwater flux-shielded arc welding process, developed through Sea Grant sponsored research, were tested under actual diving conditions in the Baltic Sea during a joint US-German project of the NOAA's Office of Manned Undersea Science and Technology in July 1976.

The development of new technology in the oceans involves dangerous exploration in deep waters by divers and men in submersibles. With Sea Grant support, Professor Thomas B. Sheridan of the Department of Mechanical Engineering is converting a manipulator, designed for aerospace and industrial application, to an undersea teleoperator with video and sonar equipped appendages for underwater operations that are now diver dependent.

M.I.T. Sea Grant, conscious of increasing demands for new energy sources, is sponsoring research by Professors Carmichael and Chiang C. Mei of the Department of Civil Engineering to investigate both the technical and economic factors involved in converting the force of ocean wave activity into electrical power.

Expanding technology in the oceans confronts Federal agencies with problems of governing offshore development. Through support from the Program in 1976-77, Professor J. D. Nyhart of the Sloan School of Management and the Department of Ocean Engineering has sought to provide assistance to public officials charged with monitoring and regulating the new industries. One model was prepared to help assess the problems resulting from both the US extended jurisdiction legislation and the potential effects of agreements reached at the Third UN Law of the Sea Conference.

Professor Nyhart also evolved a cost model using a case study of one deep ocean mining company to analyze the effects that proposed legislation, regulation, and treaty agreements could have on the economics of all the companies seeking to recover manganese nodules from the ocean beds.

During the past year, the M.I.T. Sea Grant Program continued to promote studies of marine oil pollution problems. Professor Jerome H. Milgram, using the unique low turbulence precision flume he designed and developed, contributed to the existing knowledge of oil dispersion, by accurately measuring restrained slick geometry and determining the hydrodynamic forces affecting spills and oil boom performance.

The breaking up of the Argo Merchant at sea was dramatic testimony to the inadequacy of current technical and political strategies in controlling the environmental and economic impact of oil spills. Professor Milgram, who was on board the grounded vessel, published recommendations which are of significant interest to Congressional committees concerned with international shipping law and environmental protection.

Professors Connor, Keith D. Stolzenbach, and Bryan R. Pearce of the Department of Civil Engineering completed a research project evaluating existing computer models that predict trajectories of oil slicks from original spill sites. The final study specifies data collection and modeling development needed to ensure effective oil spill control in deepwater ports and the oceans.

A major goal of the M.I.T. Sea Grant Program's research is to ensure that coastal environments remain productive while society expands the use of marine resources. Professors Connor and Pearce, in the last phase of a Sea Grant project to investigate the physical dynamic of Massachusetts Bay, expanded four models predicting the circulation and dispersion processes of the Bay. The results were documented in user manuals which are being distributed to help government and industry users establish cost-effective water quality monitoring systems.

Professor Ole Secher Madsen of the Department of Civil Engineering is studying the effects of coastal and tidal currents on long shore sediment, erosion and deposition. Sea Grant's first Henry L. Doherty Assistant Professor of Ocean Utilization, Professor Francois M. M. Morel of the Department of Civil Engineering, is continuing efforts to evaluate the great sensitivity of *Gonyaulax tamarensis* to copper toxicity in order to evolve predictive and control techniques for the dinoflagellate blooms of New England's recurring "red tides."

M.I.T. Sea Grant, while working to expand the uses of the ocean, is also concerned with the management of new and existing resources. Professor Devanney has developed a complete management plan for the Georges Bank fishery through a dynamic stochastic model that combines both economic and biologic data. The model is intended to help prevent the over-fishing of valuable stocks in the area, thereby ensuring continuing supplies for future generations of fishermen and consumers.

The Sea Grant Program's interest in preventing waste and developing underutilized living resources was reflected in the research support for the joint project of Professor David G. Wilson of the Department of Mechanical Engineering and Professor Cho Kyun Rha of the Department of Nutrition and Food Science. Professor Wilson is developing a process to mechanically skin the spiny dogfish shark using Professor Rha's analysis of its skin and flesh properties. Professor Benjamin L. Averbach of the Department of Materials Science and Engineering began a three-year project focused on the extensive characterization of chitin and its derivatives. The results of the research should provide essential information for the development of improved crustacean waste processing, which will open economic opportunities to citizens while simultaneously supplying new chemical and animal food resources.

The efforts of Professor Samuel A. Goldblith, Underwood Prescott Professor of Food Science in the Department of Nutrition and Food Science and Director of Industrial Liaison, and Mr. Pariser to quantify the cholesterol content of many commonly eaten seafood have resulted in the development of a new method of measurement, through the use of gas chromatography, which will provide dieticians, doctors, and food processors with missing, valuable nutritional information.

The problems of regional and national marine industries are a concern of M. I. T. Sea Grant. Following the development of a towing block for side trawlers, Professor Stephen P. Loutrel of the Department of Mechanical Engineering and former graduate student Clifford A. Goudey designed and tested a prototype trawl door hook-up system which would enable fishermen to more efficiently release or install the trawl door, thus allowing them to handle the nets more safely. Refinement of the trawl door itself by Mr. Clifton and Professor Vandiver is being supported by the Sea Grant Program. Using hydrodynamic principals, a new shape has been designed to effect fuel savings and reduce maintenance costs by decreasing the weight and drag of the door. Revisions will be made following current tests on board several fishing boats.

In 1975-76, results of Sea Grant sponsored research were disseminated through the publication and distribution of 18 formal technical reports.

DEAN A. HORN

Summer Session

SPECIAL PROGRAMS

One- and two-week Special Programs are presented for professional men and women who wish to keep pace with developments in their fields. Of the 57 programs planned for the 1976 session, only one program had to be cancelled because of projected low enrollment. A few were offered with quite low registrations, but the absence of cancellations is a good indicator of recovery from the 1975 recession. There was a total registration of 1,811 in the 56 programs compared with a 1975 registration of 1,635 in 56 programs.

The Special Program activity continues to have widespread appeal. Sixty percent of the registrants come from industrial and nonprofit companies, 25 percent from governmental agencies, and the remaining 15 percent from educational institutions. Two-thirds of the attendees reside east of the Mississippi River but a substantial fraction (20 percent) are from foreign countries. Approximately two-thirds of the registrants hold advanced degrees.

REGULAR SUBJECTS

Graduate students comprise 85 percent of the student body in the summer. The 1976 registration of 2,317 students represents a small increase from the 2,238 in 1975.

CONFERENCES

M. I. T. was host for a variety of conferences which included the 20th National Conference of the American Dance Guild, sponsored by the Council for the Arts; a symposium on Formulations and Computational Algorithms on Finite Element Analysis, organized by Professor Klaus J. Bathe of the Department of Mechanical Engineering; and an International Conference on Teaching Physics for Related Sciences, chaired by Professor A. P. French of the Department of Physics. Professor Glenn C. Williams of the Department of Chemical Engineering was in charge of the campus arrangements for the 1,000 people who attended the 16th International Symposium on Combustion; and Professors J. Harvey Evans and Norman Jones of the Department of Ocean Engineering were the M. I. T. hosts for the Sixth International Ship Structures Congress.

JAMES M. AUSTIN

Upward Bound Program

The M. I. T. /Wellesley Upward Bound program is a coed, multiracial, multiethnic educational program for Cambridge high school aged youth. Now in its eleventh year, the program serves 70 academically promising young men and women who have low achievement aspiration and who come from low income families. The goal of the program is to motivate these youths to attend college and to additionally provide them with the necessary academic and social skills needed to succeed in college. To a 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 and 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 young person with real success and that further success leads to an increase in his or her level of aspiration. In this process, the people around the students -- fellow students, teachers, and other program staff -- play a crucial role because what students think they can do is dependent on what others think they can do. Consequently, the students' perceptions of their abilities, and therefore what they will try to accomplish, are to a large extent determined by the program staff, who are often the first and only people to see real academic promise in the youngsters.

THE SUMMER PROGRAM

The Summer Program, conducted in residence on the Wellesley College campus for six weeks, is designed to provide the student with an intense academic and social experience. Classes are team-taught by experienced high school teachers, 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, 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 mathematics

and one humanities course, and one elective. Humanities offerings include reading and writing, the nature of prejudice, creative communication, world literature, street law, pluralism in America, Spanish, American revolution, and the psychology of social settings. Science courses include biology, ecology, and cell biology, supported in part by a grant from Sigma Xi. Microscopes and other laboratory equipment are on loan to us from the Department of Biology. The Mathematics program includes an enrichment section for students who are going to take Algebra I or II, Geometry, or Math IV; a review section for students who have done poorly in Algebra I or II, Geometry, or Math IV; as well as a computer programming course sponsored by IBM. IBM's sponsorship of these courses -- the teachers, computer terminals, and couplers -- follows several previous years of generous contributions supporting computer courses and of participation in our program.

THE 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 to cope with the myriad academic, social, and family problems that confront him in Cambridge. To achieve this, the following programs, staffed primarily by M. I. T. and Wellesley College undergraduates, have been developed and implemented.

Study Skills

The M. I. T. Upward Bound offices are open for study five afternoons a week from 3:30 to 5 p. m. and four evenings per week from 7 to 9:30 p. m. Students are asked to spend at least one afternoon or evening per week at one of these study sessions. Each session has a team of two part-time staff as leaders and, in addition, 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 College undergraduates who arrange to meet on a mutually convenient and regular basis with the Upward Bound student and then report back to project staff. For 1977-78, for the first time, space for meetings and tutoring will be available in the Cambridge public high school during the school day.

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

COLLEGE REPORT, CLASS OF 1977

Eighteen of the 19 graduating seniors have been placed in colleges as follows: Boston State College, Boston University, Connecticut College, Illinois Institute of Technology, Lincoln University, Massachusetts College of Pharmacy, Northeastern University, North Shore Community College, Pine Manor Junior College, Roger Williams College, Roxbury Community College (2), Rutgers University (2), Salem State College, Southeastern Massachusetts University, University of Lowell, and Wentworth Institute.

JOHN P. TERRY

Wellesley-M.I.T. Exchange Program

This year's report on the Institute's exchange program with Wellesley College is based on a longer document, presented earlier to the Committee on Educational Policy, which conducted during the past year an evaluation of the progress which has been made in academic cooperation with Wellesley.

The Exchange is in the best state of health it has enjoyed since its inception in 1968. We have retained the original spirit of the agreement: that the Exchange should be used to enrich the educational offerings of each institution, that it should be as free and open as possible, that it should be kept in overall financial balance, and that no money should change hands. Persistent student interest in the additional offerings made available is reflected in the fact that cross-registration has involved an average of 187 Wellesley courses and 277 M.I.T. subjects each semester. In addition, we have followed the recommendation which the Joint Committee made in its 1973 report to the M.I.T. faculty: to increase areas of direct faculty interaction and curricular cooperation. Although cooperation in several of these areas is still in the formative stages, there is ample evidence that the Exchange will become an increasingly important part of the educational program of the Institute, broadening the scope of what we do at a cost which can best be described as minimal.

Cross-registration

The cross-registration figures for the last nine years show explicitly that students take advantage of complementary faculty strengths at the two institutions. Complementarities within similar departments play an important role in this: for example, behavioral psychology at Wellesley vs. brain science at M.I.T.; natural biology at Wellesley vs. microbiology at M.I.T. Implicit in the data is the fact that students cross-register in part to take advantage of contrasting environments -- the urban atmosphere of M.I.T. and the rural setting of Wellesley College.

During the spring 1977 term, five or more M.I.T. students were enrolled in the following Wellesley courses: Art 105 Introductory Drawing, Astronomy 103 Introduction to Astronomy, Chinese 151 Advanced Elementary Chinese, Chinese 350 Independent Study, Economics 249 Seminar: The Economics of Environmental Disruption, English 109 Expository Writing, English 226 Studies in Fiction, History 253 The United States in the Twentieth Century, Psychology 101 Introduction to Psychology, Psychology 210 Social Psychology, Religion 104 The Hebrew Scriptures.

The cross-registration also benefits the Institute by providing a source of highly capable women graduate students in some areas. The most striking instance of this has probably been in architecture, in which numbers of Wellesley students have used the opportunity to register for undergraduate M.I.T. subjects to prepare themselves for entry into our graduate School of Architecture. Active discussions are under way as to how this may be done more systematically in engineering and management. An afternoon/evening symposium on opportunities in engineering, which was conducted recently by five members of our senior engineering faculty, attracted 50 Wellesley students, 20 of whom subsequently contacted the Engineering School to discuss modifications in their undergraduate programs to prepare them for graduate admission in engineering.

SPECIAL PROGRAMS

Undergraduate Research Opportunities Program (UROP)

The Undergraduate Research Opportunities Program, which has been so important to many of our undergraduates, currently provides the opportunity for about eight Wellesley students each term to become involved in research projects at M.I.T. Each spring, four of the most valuable of these UROP-for-credit projects are continued into the summer as UROP-for-pay research work with financial support from Wellesley.

Washington Internships

For many years, Wellesley has operated a highly successful Washington Internship Program, which places students in summer internship work in government. The College now contributes two or three additional positions each summer expressly for M.I.T. students.

Urban Legal Studies Program (ULSP)

The Urban Legal Studies Program, an internship program run jointly by Wellesley and M.I.T., is now entering its seventh year of summer law-related internships, research, and service projects in the greater Boston area. The primary goal of the program is to offer Wellesley and M.I.T. undergraduates who are interested in law as a career the opportunity to work with professionals in the field of law or law-related work. Approximately 45 M.I.T. students and 65 Wellesley students have applied for the 15-20 places which will be available this summer.

Winter Term / I. A. P.

For the past three years, Wellesley College has operated on an academic calendar much like M.I.T.'s with an independent activity period in January, which Wellesley calls Winter Term. Students are free to participate in the activities at either institution. A limited residence program was tried last January, with six M.I.T. students housed in Wellesley dormitories for the month.

M.I.T. / Wellesley Upward Bound Program

The M.I.T. / Wellesley Upward Bound Program has been in operation for seven years. During the summer, Upward Bound runs a seven-week academic and recreational program for approxi-

mately 70 high school students. M. I. T. and Wellesley students assist with the summer program and volunteer as tutors during the school year. In addition, there is a Saturday program for high school students during the school year.

AREAS OF ACADEMIC COOPERATION

Foreign Languages. Wellesley is cooperating in the Institute's search for a Director of Modern Languages in the Department of Humanities. There has been further cooperation in specific language areas.

Chinese. Starting with the fall 1977 term, Wellesley's Chinese Department will offer courses on the M. I. T. campus. This was made possible by the addition of half a position to the department budget. During the 1976-77 academic year Chinese 151 Advanced Elementary Chinese was offered with 11 registered students and nine listeners. Yih-jian Tai, the instructor from Wellesley, also taught an additional section of his seminar at M. I. T., Chinese Literature in the 20th Century, for which five M. I. T. students were registered. Chinese 151 continued in the spring term, with 10 students registered, and most of the students from the seminar continuing with independent study projects. Mr. Tai has developed for next year a beginning Chinese course especially for M. I. T. students.

French. A new phase of cooperation in French began in fall, 1976. Barry Lydgate, Assistant Professor in Wellesley's French Department, held a half-time (visiting) appointment in M. I. T.'s Department of Humanities in 1976-77, during which time he taught subjects in French literature and language and helped to plan future cooperation between the two institutions in these areas. The planning will continue in 1977-78, during which time he will be a full-time Visiting Assistant Professor at M. I. T. One of the M. I. T. subjects he will teach next year is 21.212 The French Novel in the 19th Century, which also has the Wellesley number French 214, and will meet alternate weeks at Wellesley and M. I. T. In addition, Assistant Professor Isabelle de Courtivron of Wellesley's French Department will hold a half-time (visiting) appointment at M. I. T. next year, and Assistant Professor Carlos Francois will teach French 302 French Literature in the 17th Century, on the M. I. T. campus.

Spanish. Beginning with the fall 1976 term M. I. T. students have been permitted to take Spanish 102 Intermediate Spanish, at Wellesley to satisfy part of the Distribution Requirement of the Humanities, Arts, and Social Sciences Requirement. During fall, 1976 term two M. I. T. students took Spanish 102. Since M. I. T. offers only the first year of Spanish, access to the courses in Wellesley's Spanish Department is important.

Far Eastern Religions. The Institute's offerings in this area lagged after Huston Smith left our faculty. There were numerous discussions between M. I. T. and Wellesley about a possible joint appointment in this area. So far, this has not come to fruition. Meanwhile, Assistant Professor T. James Kodera has been added to the faculty of Wellesley's Religion and Biblical Studies Department. He has taught the Wellesley course, Religion 108 Introduction to Asian Religions, on the M. I. T. campus this spring and will do so again in the spring of 1978.

Political Science. The Political Science departments at Wellesley and M. I. T. have been involved in an experiment in curricular cooperation, designed to take advantage of complementary faculty strengths and to mix students from the two institutions. During the 1975-76 academic year two Wellesley subjects, 311 Seminar: Private Interests and Public Issues in American Politics, and 333 Seminar: Law and Social Change, and two M. I. T. subjects 17.29 Ideology and Participation in Black American Politics, and 17.50 Political Crises in South Asia, were taught alternately

at M.I.T. and Wellesley (one week at Wellesley, the next week at M.I.T.). During the fall 1976 term, 17.22 American Political Parties was offered alternately in the same manner.

Cambridge Humanities Seminar. Wellesley College and M.I.T. (along with Brandeis University and Boston University) are members of an inter-university and interdisciplinary seminar, which began four years ago as an experiment in ways to foster both faculty and curriculum enrichment.

Known as the Cambridge Humanities Seminar, this program includes collaborative learning and teaching. Twelve faculty members from all four campuses and representing disciplines cutting across the humanities, arts, and social sciences meet in a year-long series of colloquia to discuss original papers presented by the members. The colloquia discussions lead to the development of new courses which are taught in the next academic year; frequently they are taught by pairs of faculty from the Seminar, and they are taught to classes that are open to students from all four campuses.

The Cambridge Humanities Seminar has been financed for four years with the help of grants from the National Endowment for the Humanities. The initial grant runs out this year, but the Seminar is being continued with funds contributed by the schools themselves, and there are plans to open aspects of the Seminar to a wider audience of Boston area faculty and students, if additional outside support can be found.

Archaeology/Anthropology. Wellesley College and M.I.T. are working as part of a consortium of nine educational and cultural institutions in the Boston area to establish a new center for Materials Research in Archaeology and Ethnology. The consortium has prepared three proposals through which it hopes to raise funds for a series of materials research laboratories (covering all the classes of materials encountered in the study of archaeology) for a teaching laboratory and for further planning. There are good prospects for initiating the teaching laboratory this year, and Wellesley College has submitted a strong bid for locating the facility on its campus.

The consortium also has just conducted the second year of a four-year cycle of faculty/student seminars in materials and archaeology; the sequence starts with metals and continues on through plant and animal remains, stone or lithics, and ceramics.

Faculty members from Wellesley College's newly independent Anthropology Department and from M.I.T.'s Anthropology/Archaeology Program have just begun discussions about collaboration which will include decisions arrived at jointly about the content and timing of courses taught at each school, joint listings of subjects taught, joint seminars for upper-level majors and graduate students, joint teaching of lower-level subjects to be accompanied by public lectures of interest to the general academic community.

Science. Some science departments in similar fields have cooperated in making their complementary offerings known to majors at each institution. M.I.T.'s Department of Biology and Wellesley's Department of Biological Sciences have handouts for majors which inform them about courses of special interest at the other institution and give special descriptions of these courses. Faculty in the Wellesley Geology Department and M.I.T.'s Department of Earth and Planetary Sciences have held discussions about how to take advantage of complementary offerings. One specific result was an arrangement for Wellesley students to use M.I.T. research facilities and for M.I.T. geology students to participate in Wellesley field trips.

Another interesting development this year has been the appointment to Wellesley's teaching staff of two individuals with research based work at M.I.T. It is hoped that these may lead to closer faculty ties.

Wo/men's Studies. One of the areas of greatest potential significance for the Exchange deals with the education of women and the roles of women in our society. Seen in proper perspective, this area is broader than women's studies and is variously referred to as wo/men's studies or human studies. The Joint Committee directs efforts toward promoting contact and cooperation between individuals and groups on the two campuses with interests in this general area.

During the past few years, there have been meetings between faculty from Wellesley and M.I.T. interested in wo/men's studies. Out of these grew a common course listing in the area which is publicized on both campuses. Through the special efforts of Dean Ilchman of Wellesley College, the Wellesley course, Extradepartmental 210, Contemporary Women: An Interdisciplinary Perspective, was taught on the M.I.T. campus in spring, 1975.

Through two grants from the Andrew Mellon Foundation, Wellesley will make available financial support for M.I.T. research projects in the area of wo/men's studies. These funds will be administered by Wellesley's Center for Research on Women in Higher Education and the Professions.

This year Wellesley College funded a program in the area of family and careers. Activities were scheduled during the January period at both M.I.T. and Wellesley, and a conference was held at Wellesley in March. Dr. Mary Rowe, Special Assistant to the President and Chancellor for Women and Work, and others from M.I.T. served on the Advisory Committee for the Family/Career Project. Other staff and faculty from M.I.T. served on panels during January and at the March conference.

The purpose of the project is to help Wellesley and M.I.T. students to consider how a career or non-career choice might relate to decisions about personal relationships, societal concerns, parenting, and future lifestyle satisfaction. Although the number of students participating in the March conference was not as large as expected, the conference went very well and the participants seemed on the whole to gain from the experience. With much of the groundwork laid by the project coordinator at Wellesley College and the Steering Committee (members from both Wellesley and M.I.T.), there will be more time next year to gather student input and make the project better known to students.

KENNETH M. HOFFMAN

Office of Minority Education (O.M.E.)

During 1976-77, Wesley L. Harris served as the director of the Office of Minority Education. He also retained his regular academic responsibilities on a half-time basis. One M.I.T. graduate student assisted in the research conducted by O.M.E.

Advisory Structure

O.M.E. receives the counsel of students, faculty, and staff throughout the Institute. This counsel is provided by the Minority Student Advisory Committee and the Faculty-Staff Advisory Group. Members of the Minority Student Advisory Committee for 1976-77 included: Ralph Deadwyler, David Douglass, Lisa Egbonu, Jose Fernandez, Austin Harton, Zoraida Navarro, Gary Oliver, Stanley Washington, Delonia Watson, and Gwen Wise. Members of the Faculty-Staff Advisory Group for 1976-77 included: Professors Eugene E. Covert, Ernest G. Cravalho,

Alan Davison, Charles Holt, Willard Johnson, Margaret MacVicar, Arthur P. Mattuck, Arthur Smith, Leon Trilling, and James E. Young; Deans Peter Büttner and Carola Eisenberg; Drs. Alan J. Lazarus, Mary Rowe, and Clarence G. Williams; Nelson Armstrong; and Julia C. McLellan.

PROJECTS

Assessment of Academic Performance of Minority Undergraduates

Using data from several M.I.T. offices, O.M.E. has focused upon the academic work done by black undergraduates at M.I.T. in the period from 1969 to present. In this study, O.M.E. has found that the academic performance of black students, as measured by grades and certain other indices, is on the average below that of non-minority students. The comparison uses grade point averages, grade distributions in specific subjects, overall performance in several departments, attrition rates, and performance on national standardized tests at high schools. Multiple regression analysis of the academic performance of black students indicates that SAT-verbal and SAT-math and grade sum scores are necessary but not sufficient to predict their academic performance. Within the population of black students, multiple regression analysis does not reveal any statistically significant relationship between SAT scores, grade point averages, and graduation. What remains unclear are the causes which lead to the statistically significant difference in academic performance of minority undergraduate students at M.I.T. Intragroup comparison of minority students who were PROJECT INTERPHASE participants with minority students who were not PROJECT INTERPHASE participants shows that the two subsets are not statistically distinguishable in their academic performance at M.I.T. by the end of the fourth semester.

Undergraduate Senior Minority Student Survey

A 17-page survey-questionnaire was prepared and distributed to undergraduate senior minority students in the classes graduating in 1976 and 1977. This survey-questionnaire focused on the particular students' academic and family background and admissions, academics, financial aid, and the social climate at M.I.T. O.M.E. has received a 45 percent or greater return of this survey-questionnaire in 1976 and 1977. Data contained in the returned survey-questionnaire is being analyzed, and a report will be prepared. Preliminary results of analysis of data contained in the returned survey-questionnaires do not indicate significant and meaningful correlations.

Project Interphase

This program remains a seven-week, intensive academic activity. Participants are exposed to subjects in chemistry, mathematics, physics, and humanities. An elective in computer programming is also offered. The program has a recreation and athletics component. The effectiveness and efficiency of this program have increased due to a retention of 80 percent of the 1976 teaching staff and the introduction of a humanities subject which combined a writing improvement program with reading in the general area of professionalism. Also, formal academic counseling was implemented in the program this year. This program served 33 students during 1977.

Black Student Union Tutorial Program (B.S.U. - T.P.)

This program is coordinated by minority undergraduate students with the guidance of a faculty advisor. The senior tutors are all graduate students. This program provides tutorial assistance for minority undergraduate students in more than 60 subjects and utilizes approximately 30 tutors. During the 1975-76 and 1976-77 academic years, this tutorial program logged more than 8,500 total hours of tutoring.

M. I. T. - HELP

This academic support service provides instruction in algebra, trigonometry, analytical geometry, exponentials, and logarithms for all first-year students. This service has been offered for two years and has reached approximately 35 students each year. It will be incorporated into the Black Student Union Tutorial Program.

Freshman Watch

Working with the faculty and staff teaching the science requirement subjects, this Office has been informed of the academic progress of minority freshmen. As needed, minority freshmen have been asked to come to this Office for academic counseling and for tutorial services. The program has just completed its first year (1976-77), and we believe it is most valuable. The participation of minority students has been whole-hearted and the response of faculty, staff, the Freshman Advisory Council, and freshman advisors has been cooperative.

I. A. P. Activities

During I. A. P. -1977, O.M.E. offered a series of lectures to all minority undergraduate students on systematic heuristic approaches to problem solving. The reference text was How to Solve It by G. Polya. Lectures were attended mostly by underclass students. Also, during I.A.P. -1977, O.M.E. offered a series of lectures on elements of 8.02 and 18.02 to minority freshmen. There was a significant drop in student attendance during the last two weeks of these lectures.

Tutored Videotaped Instruction (T.V.I.)

Unrehearsed, unedited videotapes of 8.02 were used for the instruction of 10 minority students during spring term 1977. These students were required to attend the regular 8.02 classroom lecture and recitation and then were assisted by a graduate student tutor in absorbing lecture material more thoroughly with the aid of a TV monitor. Educationally, an essential feature of the videotape instructional system is the ability to focus on particular segments of a given taped lecture. O.M.E., the Department of Physics, and the Center for Advanced Engineering Study collaborated on this project. Each of the students participating in this program passed 8.02 with the exception of one student who dropped the subject. In terms of both student effort and Institute resources, tutored videotaped instruction appears to be cost effective. O.M.E. plans to continue this academic service during the 1977-78 academic year. Presently, T.V.I. sessions are planned for subjects 3.091, 5.41, 6.011, 8.01, 8.02, and 18.03. This program is intended to assist students who feel that their secondary preparation is inadequate in the general area of the subject being offered.

Residence/Orientation Week 1976 Activities

O.M.E. cosponsored with the Black Student Union a series of events during R/O week 1976. The sequence of events was directed toward all minority freshmen with the objective of making the transition into M.I.T. as smooth as possible. Minority faculty, staff, and upperclass students as well as minority freshmen participated in the program. The program consisted of discussions, presentations, and films on topics such as subject selection, sources of academic support services, housing, financial aid, fraternities, athletics, security, and peer relationships.

Faculty-Student Exchange Program

This program, formally known as the Virginia State College/M.I.T. Cooperative Program, is currently supported by the US Department of Health, Education and Welfare, Title III with funding through the 1976-77 academic year. Six students from predominantly black colleges spent a total of nine semesters at M.I.T. during 1976-77, taking subjects in four of the five M.I.T. Schools. Several M.I.T. faculty visited Virginia State College for a total of 12 person-days during 1976-77 and several faculty, staff, and students from Virginia State College visited M.I.T. during spring term 1977.

FACULTY-STAFF ADVISORY GROUP ACTIVITIES

Subgroup on Tutoring

An assessment of the various tutorial programs at M.I.T. which have undergraduate students as their main clients will be valuable to O.M.E. for defining the most effective support services for minority undergraduates. O.M.E. has requested an assessment of PROJECT INTERPHASE, B.S.U. -T.P., M.I.T. -HELP, the Experimental Study Group (E.S.G.), Concourse, departmental operated tutorials, and the dormitory house tutoring programs. This essential task is being handled by a subgroup of the Faculty-Staff Advisory Group. Membership in this subgroup consists of Professors Lazarus (Chairman), Cravalho, Holt, Mattuck, Young, and Ms. McLellan. The subgroup recommended the establishment of an academic counseling component and the use of experienced senior faculty as teachers in PROJECT INTERPHASE. It also recommended that an advisory group be formed to monitor the progress of the Black Student Union Tutorial Program, and that this program receive strong faculty input.

Faculty-Staff Survey Subgroup

In order to obtain a more complete perspective of the general academic health of minority undergraduate students at M.I.T., O.M.E. continues to seek the views of faculty and staff on this matter. Specifically, O.M.E. seeks an understanding of how better to enhance and maintain the general academic health of minority undergraduate students and a clearer formulation of how faculty and staff can better assist minority undergraduate students in various facets of their student life. Membership in this subgroup consists of Drs. Rowe and Williams (Cochairpersons), Mr. Armstrong, Dean Büttner, and Professors Covert, Davison, Smith, and Trilling. The following observations were made by the group:

- 1) Adapting to M.I.T. and its pressures is a problem for most students. The increased competitiveness as compared with high school and a perceived pressure to succeed often lead to difficulties. There are barriers between students and faculty arising from age differences

and from the perception of the faculty as highly successful and competent. This leads to lack of questions from the students and a loss of student confidence in their own abilities. Students with clearly defined goals and motivation find adjustment less of a problem. There is also a problem of adjustment to the general Boston area.

- 2) The minority staff did not have much student contact and would welcome more direct association with students. The intimidating effects of faculty reputation and the generation gap are apparent here as well.
- 3) The lack of minority staff was mentioned particularly in the Medical Department. In this case, problems arising from unfamiliarity with this type of service were accentuated by lack of staff. The need for role models in general also was expressed.
- 4) The degree of M.I.T.'s commitment to dealing with these and other problems of minorities was questioned. A particular concern was expressed with respect to living arrangements and housing policy for minorities.
- 5) Minority students' expectations are more likely to be at variance with the realities of life at M.I.T.
- 6) The minority staff and faculty expressed considerable concern for the difficulties of minority women at M.I.T.
- 7) The question of career counseling is probably more important for minorities than non-minorities.

These observations are the interpretations of interviews of 34 minority staff and faculty members.

National Workshop on Minority Undergraduate Education in
Science/Engineering

O. M. E. is working with Dr. Williams and the Committee on Minorities in Engineering of the National Research Council to obtain funding from sources outside M. I. T. to address the areas of academic support services and retention of minority undergraduates in engineering. A proposed series of related workshops would involve a limited number of colleges, universities, and institutions similar in nature and range to M. I. T. The workshops would occur at M. I. T. and would take place in fall, 1977 provided funding is obtained.

WESLEY L. HARRIS



School of Architecture and Planning

At a time when the School enjoys a secure national reputation as vigorous and innovative, many factors combine to create special difficulties here at M.I.T. It is most ironic that the possibility of taking a major step ahead, of realizing the School's potential for national leadership, may now be compromised if the problems I shall spell out below cannot be solved. After a period of rapid expansion in many areas, the School -- along with the rest of M.I.T. -- has been compelled to adjust to an era of non-growth or even of slight decline as the Institute enters the last stages of balancing its budget. This adjustment is taking its toll in student aid, junior faculty development, affirmative action, attitudes of the senior faculty, and space.

While applications and enrollments have increased over the last several years despite the uncertain job market, the larger number of students coupled with increases in tuition and the reduction of funds for student support have diminished our capacity to help students meet their expenses.

The senior faculty feel under considerable pressure to seek outside funding for their research and curriculum development that would pay part of their salary, provide support for student research assistants, and cover the necessary space modification costs. For many this is a challenge, but for others it is unfamiliar and uncomfortable, and for some it may even be inappropriate.

Gains in affirmative action have been hard to sustain. The financial difficulties have served to make more evident the profundity of years of relative deprivation and isolation of minorities in American society. Our conviction is stronger than ever to maintain a vigorous and effective affirmative action program. Unfortunately, an inevitable frustration has resulted from the combination of our policy and declining resources.

Junior faculty development today occurs in a different ambience than several years ago. As fields are culled from our programs and as the faculty becomes more limited in size, the prospects for junior members to remain at M.I.T. are becoming increasingly dim. We have, in fact, become more like other schools at the Institute which have been in the state of non-growth for some time now. In our present situation, a career for a junior faculty member most likely means leaving the School. This shift from a growing to a slightly declining school has been particularly difficult among the junior faculty who started with high hopes -- realistic a few years ago -- and who now must lower their expectations. The shift has, of course, caused friction and increased the need for sensitivity toward the career needs of the junior faculty. It requires new relationships between them and senior faculty and the Department Heads. The departments are, in fact, working out such relationships, but it takes time.

The Committee for Review of Space Planning (C.R.S.P.), the Planning Office, and the Office of Design and Construction have all worked hard to satisfy the space needs of the School. Our space problem, nevertheless, remains severe. Much of it is in poor condition, and there are not adequate monies foreseeable for rehabilitation. This prevents a more intensive utilization of the available space. Therefore, while occupying large areas which remain underutilized because of their condition, we are forced to request additional space for new activities as

they develop. Several possibilities both in the main buildings and other locations to accommodate the School's space needs have been raised. The field of possibilities, however, continues to shift, making it extremely difficult to plan for the immediate let alone the distant future. These shifts, coupled with the present condition of the space, have created what I would call the most serious administrative problem in the School.

There has been progress on the Leadership Campaign for this School. Several prospective donors have been approached for a Chair in Building Technology; good contacts have been established with the Development Office to identify individuals and foundations that might be good prospects for the School; and the School's Leadership Campaign brochure has been approved with minor modifications. Nevertheless, the Leadership Campaign for the School seems to be a distant promise. There are special difficulties we have within M. I. T. as a whole which may require even more vigorous and extraordinary action. The action may be impossible because of the way in which the Leadership Campaign is organized and because of the nature of existing commitments. The School's alumni are not wealthy. The clients of our graduates in the planning field are not apt to be wealthy, particularly because of our policy to include more minorities among our students, and because there has been a secular shift away from architecture in particular as a profession of the rich. Our students are becoming needier because of the lack of government support for research in architecture and planning. The financial requirements of the students cannot be completely met through funded research programs in the School, although much progress has been made over the last few years. The starting and top salaries of our graduates tend to be low compared to those of other M. I. T. graduates. Also, potential donors do not first think of architecture and planning when they think of M. I. T. These realities make the Leadership Campaign more difficult for the School. As a consequence, there results an aura of unreality which undermines the confidence of the faculty and leadership of this School in getting tangible results.

Organizationally, the School is handling its size in an encouraging way, permitting student participation and at the same time retaining the prerogatives of the faculty in the essential areas of decision making. New degree programs have been created to bring about a better interaction between this School and other schools at M. I. T. to facilitate capitalizing on intellectual resources elsewhere at the Institute. The heightened and refreshing interest of the faculty and students in the substance and form of contemporary professional practice -- as compared to its recent rejection by many students -- is being matched by an active desire on the part of alumni to rethink the nature of their own profession. All this promises new professional definitions.

COMPOSITION OF THE SCHOOL

Faculty and Staff

The number of faculty in the School has decreased from 80 in 1975-76 to the present 68. In the Department of Architecture, the number dropped from 42 to 37, and in the Department of Urban Studies and Planning (D. U. S. P.), from 40 to 33. The decreases reflect a new trend in the School, where the size of the faculty has been consistently growing over the last few years. In 1970-71 there were 52 faculty members in the School.

Two professors held joint appointments in the two departments (as compared to four last year). The equivalent full time (E. F. T.) faculty count was 62 3/4 this year (67 last year) with 33 in Architecture and 29 3/4 in the D. U. S. P. The number of women on the faculty went up in Architecture from six to seven, down in the D. U. S. P. from five to four. The number of minorities in the faculty declined by two in both departments: from four to two in Architecture and from seven to five in the D. U. S. P.

Other academic staff in the School (lecturers, instructors, and senior lecturers) totaled 30 this year (20 last year) with 19 in Architecture, nine in the D. U. S. P., and two in the Laboratory of Architecture and Planning. Of these, there were four women and one minority person in Architecture, two women and two minority persons in the D. U. S. P. The School's research staff totaled 18 this year, including three women and one minority person. Of this total, 11 (three without pay) were in Architecture, two in the D. U. S. P., and five in the Laboratory of Architecture and Planning.

Students

Student enrollment for 1976-77, based on a five-week count taken during the fall term, was 520 (as compared with 504 last year). A six-year comparison with enrollment figures for 1970-71 shows an increase of 14.8 percent over the total of 453 students that year. The number of special (non-degree) students was 46 for 1976-77 (50 last year and 50 in 1970-71). Of special students, nine were in the Community Fellows Program, which enrolled no students last year.

The number of women students over the period of six years has grown from 84 to 173, an increase of 105.9 percent. Of the 173 women, 98 were in Architecture and 75 in Urban Studies and Planning. Women comprised 33 percent of the student body, and members of minority groups 16 percent. There was a slight increase in women and minority representation. Last year, the percentages were 29.1 percent for women and 13.1 percent for minorities. Departmentally the figures for 1976-77 were: in Architecture women made up 29 percent (26 percent last year) and minorities 10.3 percent (9 percent last year); in the D. U. S. P. 42 percent (35 percent last year) of the student body were women and 26.7 percent (21 percent last year) were members of minority groups.

During 1976-77, the School enrollment was 6.3 percent of the total M. I. T. enrollment (6 percent in 1970-71). A table below shows the School's 1976-77 enrollment and composition.

STUDENT ENROLLMENT AND COMPOSITION 1976-77⁺

	<u>Total</u>	<u>Women</u>	<u>%Women</u>	<u>Minority</u>	<u>%Minority</u>	<u>Foreign</u>	<u>%Foreign</u>
<u>Department of Architecture</u>							
Undergraduates	134	32	23	4(NA) ⁺⁺	2.9	11	8.2
M. Arch.	112	42	38	24(4)	21.0	8	7.1
M. Arch. A. S.	49	10	20	4(1)	8.2	32	65.0
M. S.	14	2	14	1(0)	7.0	1	7.0
Ph. D.	8	4	50	0(0)	0	5	63.0
<u>Special Students</u>							
Undergraduate	5	1	20	0(NA)	-	3	60.0
Graduate	11	6	55	0(0)	0	3	27.3
Joint M. Arch. / M. C. P.	3	1	33	2(1)	66.0	0	0
Joint M. Arch. A. S. / M. C. P.	4	0	0	0(0)	0	2	50.0
<u>Department Totals</u>	<u>340</u>	<u>98</u>	<u>29</u>	<u>35(6)</u>	<u>10.3</u>	<u>65</u>	<u>19.1</u>
<u>Department of Urban Studies and Planning</u>							
Undergraduates	50	16	32	10(5)	20	1	2.0
M. C.P.	44	24	55	22(12)	50	4	9.0
Ph. D.	46	17	32	6(3)	13	11	24.0
<u>Special Students**</u>							
SPURS***	10	1	10	0(0)	0	10	100.0
C. F. P. ***	9	5	55	9(5)	100.0	0	0
Other	11	9	82	NA(NA)	NA	2	18.0
Joint M. Arch. / M. C. P.	3	1	33	0(0)	0	1	33
Joint Civil Eng. / D. U. S. P.	7	2	29	1(0)	14	0	0
<u>Department Totals</u>	<u>180</u>	<u>75</u>	<u>42</u>	<u>48(25)</u>	<u>26.7</u>	<u>29</u>	<u>16.1</u>
<u>School</u>							
Undergraduates	184	48	26	14(5)	7.6	12	6.5
Graduates	290	103	36	60(21)	20.7	64	22.1
Special Students**	46	22	48	9(5)	19.6	18	39.1
TOTAL ENROLLMENT	520	173	33	83(31)	16.0	94	18.1

+ Enrollment figures are a five-week count of students registered in the fall

++ Not available

** Non-degree candidates

*** Special non-degree programs in the Department of Urban Studies and Planning:

The Special Program for Urban and Regional Studies of Developing Countries (SPURS), begun in 1967, and The Community Fellows Program (C. F. P.), established in 1971.

DEGREE PROGRAMS AND ADMISSIONS

In the academic year 1976-77, there were 997 applications for 126 targeted places. Actual enrollment of new students in the degree programs in the fall term totaled 107 (111 last year). This year's number of applications decreased by 13 from last year's 1,010. The most notable increase occurred in the one-year old Ph.D. program in the Department of Architecture from 16 applications (for three targeted places) to 34 (for seven targeted places). There was a notable decrease of applications for the M.C.P. program in the D.U.S.P. from 399 last year to 267 this year. The D.U.S.P. did a study of the decrease and found no drop-off in the quality of the applications, which is as high if not higher than last year. The number of applications to the other degree programs remained relatively even, producing an overall ratio of applications to targeted places of about nine to one consistent over the last few years.

The degrees awarded to the School's students in September 1976, February 1977, and June 1977 totaled 135, of which 93 were in the Department of Architecture and 41 were in the D.U.S.P. Certificates were given to 10 Fellows (11 last year) in the Special Program for Urban and Regional Studies of Developing Countries (SPURS) for completing a year of study at the Department of Urban Studies, where SPURS is a special non-degree program. Also, certificates were given to nine Fellows in the Community Fellows Program (C.F.P.), another special non-degree program in the D.U.S.P.

In the Department of Architecture, the 93 degrees were distributed as follows: 46 students received a B.S.A.D. & S.B.; 27 students received an M.Arch.; 20 an M.Arch.A.S. In its second year, the Department's Ph.D. program gave no degrees.

In the Department of Urban Studies and Planning, 12 students received an S.B.; 23 students received an M.C.P.; and six students received a Ph.D. Altogether, 135 (145 last year) of the 474 (454 last year) enrolled in the School's degree programs in 1976-77 received degrees.

SCHOOL NEWS

The School's Visiting Committee, chaired by Norman B. Leventhal, met on April 21 and 22, with 16 of its 18 members attending. The members met with the Dean, Department Heads, other members of the School Council, faculty, students, and Institute officials. The Committee discussed professional effectiveness in the practice of architecture and planning; the viability of the School's central educational themes in today's American society; and the School's involvement in the Leadership Campaign. The Committee also reviewed the teaching and research programs with faculty and students.

Technology Day was celebrated on June 9 to strengthen the ties between alumni/ae and the School. On Friday, June 10, the Department of Architecture held an informal faculty panel on "Design Education and Research" and shared views with alumni/ae about educational programs, research, and student work. The Department of Urban Studies and Planning discussed "Education for Professional Competence." Using the Department's past and present curricula as basis, they exchanged thoughts on what skills and perspectives are essential for creative practice.

The Louis Skidmore Room was dedicated on November 19, 1976 to house the Rotch Library Visual Collections. The renovation by Lyndon Associates was made possible in part by a gift from Skidmore, Owings, and Merrill in memory of Louis Skidmore.

The Independent Activities Period (I. A. P.) was formally, for the first time, open to practitioners. Forty-five architects and planners from state agencies, town planning boards, and private agencies around Massachusetts attended. These seminars were coordinated by William Ronco and run through the Laboratory of Architecture and Planning.

The School Council met 19 times during the academic year. Much time was spent in discussing the severe space problems of the School. Other recurring themes were departmental research plans; Leadership Campaign and, more specifically, identification of potential sources of funding for the School; continuing education (summer and winter courses); and the School's admissions, appointment, and reappointment policies.

The Laboratory of Architecture and Planning, partly because of David Judelson's resignation as Assistant Director of the Laboratory, remained an important topic as new guidelines emerged and called for redefinitions of the Laboratory's role in the School. Also, its relationship with the Joint Center for Urban Studies of M. I. T. and Harvard was seen as a possible area for reconsideration.

Ann Gordon, Assistant Dean for Academic Administration, resigned as of May 30. Florence C. Ladd, Associate Professor in City Planning at the Harvard Graduate School of Design, was appointed the new Assistant Dean for Academic Administration.

A number of publications originated in the School. The three-year old Newsletter, published each term by the Dean's Office, was renamed PLAN-Review of the M. I. T. School of Architecture and Planning to reflect the change that had been taking place in the past 14 months from a predominantly School news oriented publication to one that also reflects some of the approaches, attitudes, and philosophies of various faculty members and students as well. The review provides the School's major link with its nearly 3,000 alumni.

The Architecture Machine Group, directed by Professor Nicholas Negroponte, started a second year of publication of Architecture Machinations, a weekly newsletter originally produced to encourage internal communication among the members of the Group. It is now requested by many groups and individuals outside the Department and M. I. T. as a valuable source of information on computer aided graphics.

Professor Robert Hollister continued to publish his weekly Know One City Well, which was supported by the Department of Urban Studies and Planning. The publication was designed to alert members of the School, and others who might be interested, to places and events of special note in Boston.

Students in the Department of Architecture put out several issues of Bullform, aimed at the student population of the Department. As there did not seem to be a demand for this kind of paper any more, Bullform was replaced by Newsletter, a more professionally oriented publication. The D. U. S. P. continues to publish The Final Daze, a graduate student guide to the academic and research programs, administrative procedures, and who's who in the Department.

WILLIAM L. PORTER

Department of Architecture

Deliberation and implementation of new policies, gradual reorganization of curriculum, and evaluation of processes and goals characterized the Department's activities for 1976-77.

The Policy Committee resolved issues of full-time faculty loads and sabbaticals. It reviewed various recommendations of the degree program committees and some discipline groups, and initiated a reappraisal of the current Master of Architecture in Advanced Studies Program as a possible vehicle for a more comprehensive research-teaching program.

A newly established Standing Committee on Appointments developed procedures that make promotions, reappointments, and searches more understandable for all Department faculty. The Committee was chaired by Professor Sandra Howell, and members were Professors Maurice Smith, Richard Leacock, and Stanford Anderson and Research Associate Timothy Johnson.

The degree committees came forward with important recommendations to the Policy Committee. The Master of Architecture Committee, chaired by Professor Imre Halasz, deliberated the role of thesis in the Master of Architecture Program. The Undergraduate Program Committee, chaired by Professor Edward Allen, improved the organization of Department curriculum and its communication to our undergraduates.

The year 1976-77 was the first full year of operation for the Master of Science degree program with 14 students enrolled. Professor Nicholas Negroponete chaired the Master of Science Degree Committee, which will continue to develop this program in visual studies, computer-aided design, film and video, and building technology.

Department faculty discipline groups explored directions for the future. The Visual Studies Discipline Group met frequently to discuss coordination and cooperation in research and teaching among the various groups: the Film Section, the Creative Photography Laboratory, the Visible Language Workshop, the Visual Studies Group, and the Center for Advanced Visual Studies. Several faculty members from outside this discipline group were invited to join the deliberations, chaired by Professor Donlyn Lyndon. As a result, a steering committee was formed by Professors Negroponete, Otto Piene, and Richard Leacock. The group dealt especially with the Visible Language Workshop in recommending closer cooperation among these groups in some specific areas of teaching and research, and proposed a plan for new appointments to strengthen this policy. These recommendations were accepted for implementation. The steering committee particularly faced the need for more funded research in the Visual Studies area; it continues to develop research plans and seek funding for them.

The Building Technology faculty met frequently with colleagues from the Department of Civil Engineering and the Harvard Graduate School of Design to seek a more comprehensive programming of courses in building technology and to determine the nature of new appointments. This group, chaired by Professor Edward Allen, came forward with a thoughtful and innovative report on how to teach building technology in a department of architecture and suggested experimental course for next year. Recommendations were made for new appointments. The group's deliberations yielded a much better understanding of the mutual faculty interests and complementary activities in the three different departments, opening a way toward more effective cooperation.

Urbino

Seven M. I. T. students participated in the first session of the International Laboratory of Architecture and Urban Design in Urbino, Italy, with Professor Julian Beinart representing the M. I. T. faculty. The Laboratory is under the direction of Giancarlo di Carlo, Professor of Architecture at the University of Venice, and involves collaboration of students from four European universities with those from M. I. T. The program will continue in the coming year with Professor Donlyn Lyndon leading the M. I. T. group.

Lectures and Events

An informal faculty panel, "Design Education and Research," was held for visiting alumni on the annual Technology Day on June 10. Department faculty discussed their ongoing research emphasizing the role research plays in our education.

The second annual Lawrence B. Anderson lecture was delivered on May 13 by Denise Scott Brown, architect and partner in the firm of Venturi and Rauch, Architects and Planners, Philadelphia. She also is a member of the School's Visiting Committee. Ms. Scott Brown spoke on "The Forgotten Symbolism of Architectural Form."

Grants and Awards

The Department received generous support from a number of organizations. The Louis B. Mayer Foundation contributed substantially to the growth and activities in the Film Section, The Graham Scholars Fund helped thesis students to cover unusual expenses in outstanding projects, and the Graham Fund supported the Visible Language Workshop.

The Louis B. Skidmore Fund assisted the Department in participating in the International Laboratory of Architecture and Urban Design. The Albert J. Hinckley, Jr. Traveling Fellowship was awarded to George Tremblay, Jenny Scheu, Abraham Ford, Linda Brown, and Mohammed Abdus-Sabur for outstanding research travel proposals.

American Institute of Architects (AIA) Scholarship Awards for 1977-78 were presented to four Master of Architecture candidates: George Tremblay, Mary Griffin, Kay Barned, and David Chandler. Five Master of Architecture recipients won special prizes. The AIA Medal was given to Mitchell Green, and the AIA Certificate to Joan Leung. The Alpha Ro Chi Medal for Service to the Department was awarded to Nicholas Elton. The Chandler Prize was presented to Patty Seidman and the Chamberlain Prize to Robert Osten.

Space and Facilities

Again this year the lack of appropriate and less dispersed spaces and shop facilities affected students, faculty, teaching, and research in almost all segments within the Department. The space topic tends to dominate and replace many other concerns of vital importance.

RESEARCH

The Department continues to consolidate its position as a leader in architectural research. This year's full and productive research agenda involved faculty and students joining diverse areas of interest. Our research volume for 1976-77 totaled \$785,340 and extended from explorations in computer graphics and visual arts to housing and street patterns in American cities.

Projects in the Architecture Machine Group, under the direction of Professor Negroponte, including the following: Augmentation of Human Resources in Command and Control through Multiple Media Man-Machine Interaction; television-based animation; touch sensitive display; color perception; computer graphics mapping; Multics-graphics support; idiosyncratic systems; machine recognition and inference making; advanced technology display systems.

Through these projects, the Architecture Machine continues to build bridges to other areas, particularly mechanical engineering, visual studies, and urban planning. The accessibility of computer systems for widespread human use continues to be a strong direction for the Architecture Machine Group.

The Department's other research projects were: continuation of the Urban Form Analysis project under the direction of Professor Stanford Anderson; Examination of Historical Patterns and Change in San Francisco Neighborhoods under the direction of Professor Anne Vernez-Moudon; Exploration of Space Conditions with Variable Membranes, a Solar Energy Building Technology project, under the direction of Mr. Johnson; Information Transfer Strategy for the Elderly under the direction of Professor Howell; Modular Coordination in Building Systems under the direction of Professor John Habraken; Housing and the Construction Industry in Egypt, a part of the Technology Adaptation Program under the direction of Professor Habraken.

A number of architecture schools are beginning to develop their research activity and to this end, the American Institute of Architects has formed an Architectural Research Centers Consortium, of which M. I. T. is a founding member.

FACULTY

The Department welcomed a number of new faculty members and visitors during the year. Starr Ockenga was appointed Assistant Professor of Photography and Steven Gregory, Assistant Professor of Computer-Aided Design.

Giorgio Ciucci, Professor of Architecture at the University of Venice, Italy, and Peter Prangnell, Professor of Architecture at the University of Toronto, were Visiting Professors. Lo-Yi Chan, Vivian Loftness, Mardges Bacon, and Leslie Larson were Visiting Lecturers. The Department welcomed Herman Hertzberger, a Dutch architect, for one week in the spring to serve as a visiting critic.

Professors Whitney Chadwick, Dolores Hayden, and Robert Slattery were appointed to the rank of Associate Professor.

Professor Henry A. Millon continued on his extended leave as director of the American Academy in Rome. The Department is looking forward to Professor Millon's return in fall, 1977. Professor Waclaw Zalewski was on leave as consulting engineer in the Department of Architecture at the Universidad Central de Venezuela in Caracas. Professors Beinart and John Myer were on sabbatical leave, and Professor Sean Wellesley-Miller was on leave to develop his solar energy research. Professor Chadwick was on leave during spring term as a visiting professor at the University of California at Berkeley. Professor Hayden was on leave as a fellow at the Radcliffe Institute under a research grant from the National Endowment for the Humanities.

Professor Emeritus Albert G. H. Dietz received the Man of the Quarter Century Award from the Building Research Advisory Board of the National Research Council. Professor Robert B. Newman was also honored with a Quarter Century Citation, "for significant and lasting

contribution to the State of the Art of Building Science and Construction Technology." Professor Leacock received an honorary Doctor of Fine Arts degree from the Minneapolis College of Art and Design. Professor Stanford Anderson received a grant from the American Council of Learned Societies.

Professor Eduardo Catalano resigned after 18 active years. The Department recognizes with gratitude his ability to combine the experience from a prestigious architectural practice with his teaching, which attracted students from all over the world.

Professor Donlyn Lyndon assumed the chairmanship of the Institute Committee on the Visual Arts. Professor Lyndon, who also is current president of the Association of Collegiate Schools of Architecture, received an honor award in the "Boston Exports" program from the Boston Society of Architects for student housing at Pembroke College of Brown University.

Robert O. Preusser, Professor of Visual Design and Director of Education at the Center for Advanced Visual Studies, participated in the UNESCO International Symposium in Paris, France.

Dean Emeritus Lawrence B. Anderson was Thomas Jefferson Visiting Professor of Architecture at the University of Virginia for fall term.

A number of Department faculty made important contributions to the successful "Women in American Architecture" show at the Hayden Gallery. Professors Hayden and Anne Vernez-Moudon were instrumental in organizing the exhibit, and Professor Hayden delivered a lecture developed around the exhibit and her own research on the domestic ideal.

Professor William H. Brown, who retired in June 1976, died on November 5, 1976.

Faculty Publications

Camino, Horacio, with Reinhard Goethert. Urbanization Primer for Design of Site and Service Projects, Washington, DC, World Bank, Urban Projects Department, 1976.

El Precio de la Dispersion Urbana, with Carlos H. Camino, Merida, Venezuela, Universidad de los Andes, 1977.

Dluhosch, Eric. "Involving People in the Housing Process--The Story of Habraken's 'Supports and Detachables'." Industrialization Forum, Vol. 7, No. 1, pp. 3-5.

Habraken, N. John. Variations: The Systematic Design of Supports, M.I.T., The Laboratory of Architecture and Planning, 1976.

Hayden, Dolores, with Gwendolyn Wright. "Architecture and Urban Planning," in Journal of Women in Culture and Society, Vol. 1, No. 4, pp. 923-933.

Seven American Utopias: The Architecture of Communitarian Socialism, 1790-1975, Cambridge, M.I.T. Press, 1976.

"Challenging the American Domestic Ideal," and "Catherine Beecher and the Politics of Housework," in Women in American Architecture, Susanna Torre, ed., Watson and Guptill, 1977.

"Collectivizing the American Workplace," in Lotus: Rivista Internazionale di Architettura Contemporanea, Milan, No. 12, Summer, 1976.

"Skyscraper Seduction, Skyscraper Rape," in Heresies, Vol. 2, 1977.

Howell, Sandra, Principal Investigator, "Shared Spaces in Housing for the Elderly," M. I. T., Department of Architecture, 1976.

"Site Selection, The Neighborhood as Window to the World," in Community Planning for the Elderly, Newcomer, Lawton, and Byerts, eds., Dowden, Hutchison and Ross, 1976.

"Adapting Environments for the Developmentally Disabled," in Developmental Disabilities: Psychological and Social Implications, Bergsma and Pulver, eds., National Foundation March of Dimes, 1976.

"Post Occupancy Evaluation Transfer Strategy," in Industrialization Forum, 1977.

Johnson, Timothy. "Performance of Passively Heated Buildings," Journal of Architectural Education, Vol. XXX, No. 3, 1977.

"Lightweight Thermal Storage for Solar Heated Buildings," Solar Energy, p. 461, 1977.

Lyndon, Donlyn, with Karen Wheeler. "M. I. T. Arts Environment Study," M. I. T. Council for the Arts, Boston, 1976.

"Donlyn Lyndon" in Architecture et Urbanisme, "Forty under 40," Robert Stern, Vol. 77, No. 1, January 1977, p. 113.

Preusser, Robert. "Colored Illumination and the Environment," in Colour for Architecture, Thomas Porter and Byran Mikellides, eds., London, Studio Vista, 1976.

"Report on the 1975 International Art Transition Conference at the Massachusetts Institute of Technology" in Leonardo, Pergamon Press, Ltd., Vol. 9, No. 3, Summer, 1976.

Vernez-Moudon, Anne. "Les Marelles: Lessons in Dwelling Design," in Industrialization Forum, Vol. 7, No. 1, pp. 47-56.

Wampler, Jan. All Their Own: People and the Places They Build, New York, John Wiley & Sons, 1977.

N. JOHN HABRAKEN

Department of Urban Studies and Planning (D.U.S.P.)

During the academic year 1976-77, three themes continued to hold a central place in the concerns of the Department of Urban Studies and Planning: 1) curriculum review of the degree programs, 2) the Department's governing processes, and 3) the role of research. In addition, several new themes of critical importance have emerged.

Curriculum review has still been a central issue in all three degree programs. The undergraduate program in particular has been subjected to a searching analysis, and significant structural changes have been recommended. The "core courses" in the Master's Program are an established fact at this point. The question is how to extend those core elements into more self-evident "streams" of courses beyond the introductory level.

The Department's governing processes have remained the same, with one exception: the Appointments Committee has been eliminated and its functions assumed by a Committee-of-the-Whole of the tenured faculty.

The role of research and its relationship to financing faculty and students has extensively occupied both the Department's Policy Committee and the senior faculty.

RESEARCH

As indicated in the past two annual reports, the issue of research -- who has it, for how much, and for what -- is a major departmental topic of debate and discussion. Last year we told how Bemis funds had been used to "seed" research clusters. That seeding has had mixed results. While the research dollars have not poured in, there have been some hopeful signs that such seeding makes sense in developing a more structured approach to a Department research agenda.

The major issue around research evolved from the Department's policy that faculty members be responsible for covering one-quarter of their base salary with research dollars. The general principle of research "buy-out" is a regular aspect of academic life elsewhere in the Institute. Even if we have successfully institutionalized the principle of the "buy-out," several members of the faculty questioned whether the practice was useful and/or appropriate. Perhaps a department should not require faculty to raise their own money; and perhaps the faculty should be cut back to a size that could be totally covered by general funds.

The Department's research policy thus raised the more general issues of faculty size, faculty responsibility for raising salary-related dollars, and, most fundamentally, the "quality of life" that results from the necessity of having to raise dollars every year to cover part of one's pay.

After extended discussion at both the Policy Committee and the senior faculty level, there was general agreement that the principle of the "buy-out" made sense. It enables us to have a wider ranging, more diversified faculty than would otherwise be possible; and it pushes us to do sponsored research, which given the nature of the field in which we are engaged, is critical and necessary. Without research we would not be involved on the frontiers of knowledge and action. Without research we would have no way of engaging our students in joining learning enterprises let alone helping them to pay for the increasingly burdensome costs of education.

While there was a reaffirmation of the general principle of research "buy-out" as an institutionalized way of doing business in the Department, clear recognition also emerged that not everyone could raise funds all the time and that we simply must find means of ensuring that different styles, patterns, and cycles of research are both recognized and acceptable. While there was general support for keeping the faculty as diversified and broad gauged as possible, there was also an awareness that size for the sake of size is not always a good thing, particularly in a time of diminishing resources and rising costs.

The intensity of the discussion and the number of forums in which it occurred gives us some idea of how central financial questions -- for both faculty and students -- have been in the Department this year. While we have emphasized the anxiety and discontent caused by the continued hammering of the departmental budget, the problem was intensified this year not only by faculty concerns for the "buy-out," but also by the fact that for the first time the financial aid package we offered students was significantly below tuition.

It is both repetitious and in some sense gratuitous to focus on money problems; but they are very real and very much a part of the news of the year. But the year was not all old theme and financial squeeze. Two substantive areas -- the Environmental Arena and Public Policy -- engaged the Department in a central way.

The Environmental Arena

Last year under future prospects we talked about the need to:

"strengthen the Department's resources in its traditional center of activity, namely urban growth and land use policy and to extend those resources into emerging issues of environment, energy and development planning."

This year Environmental Arena -- a new major theme in the Department -- has been expanding and gaining strength. Professor Lawrence Susskind's project with the Energy Research and Development Administration has been focusing on new ways of dealing with the social and environmental consequences of energy extraction facilities. A number of impressive papers and student theses have emerged from the project. The fact that the project has been refunded under Professor Michael O'Hare's direction for another year and that it warranted a front page article in the Wall Street Journal are indications of its success. In addition, the Department's central role in the Rockefeller Foundation's grant to the Institute to study the environmental and institutional impact of large-scale facilities has been a further extension of the Department's role in the environmental field. The appointment of Professor Lawrence Bacow to work on the Rockefeller project and to teach in the expanding undergraduate program in environmental planning is yet another sign that we are moving forward in this arena.

Public Policy

During the course of the year, the issue of public policy emerged for several reasons as one of the central concerns to the Department. First, the Institute-wide Applied Social Science Committee, chaired by Professor Robert M. Solow of the Department of Economics, was created to look at the issue of applied social science in the Institute and to focus on issues of public policy at M. I. T. Secondly, the Department of Political Science has been awarded a one-year grant from the Sloan Foundation to establish an undergraduate program in public policy, a project in which the D. U. S. P. has been deeply involved. Third, the Ford Foundation has recently solicited a proposal from the Institute concerning the establishment of a public policy program at the graduate level. While it is clear that the Department has always been at the center of the Institute's public policy endeavors, an emerging question is what that role will be as public policy becomes a concept explicitly talked about in institutional terms throughout M. I. T.

In addition to new general areas of substantive involvement, the traditional degree and program group represents the center of the Department's activity.

M. C. P. Program

The academic year 1976-77 marked the second year of the new M. C. P. curriculum. One of the major elements of that curriculum has been the institution of four required "core" courses: Planning Process, Economic Analysis for Planners, Methods for Urban Studies and Planning, and an institutional analysis subject.

In January 1976, the first group of M. C. P. students to complete the required courses participated in an open review session during which it was concluded that "core courses better prepared M. C. P. students both in basic knowledge and in the ability to apply such knowledge in a planning context." The core was again the focus of extensive evaluation this spring. Hearings were held in an effort to surface concerns from students and faculty about the core.

Transcripts of the hearings were reviewed by the M. C. P. Committee which then circulated, for students and faculty comments, potential recommendations for strengthening particular core courses.

Key modifications to the core growing out of the review process include the rescheduling of the Planning Process course to the spring to better distribute the work load of first-year students, and various changes of focus in the four required subjects. For example, the comparative theoretical components of the Planning Process course will be bolstered; the Methods course will increase emphasis on generic methodological skills while deemphasizing particular analytic techniques; the topical scope of the economics core course will be expanded while reasserting the importance of covering more traditional microeconomic theory; and the nature of the institutional analysis course requirement will be redefined.

The core review process was a positive experience for those involved. It reaffirmed the confidence of students and faculty in the core and produced specific measures for change which are responsive to student and faculty opinion.

In addition to admissions activities, the M. C. P. Committee undertook end-of-semester reviews of student academic performance.

Administrative efforts were stepped up to ensure that faculty advisors took responsibility for each student's program statement (a plan and timetable for the completion of all phases of the M. C. P. program), for term-by-term selection, and for adding or dropping decisions during the semester.

The format for recording information on enrollment patterns and on students' academic performance was redesigned. This new information management system will be computerized next year to facilitate analysis of the changing demands for particular subjects and to review de facto enrollment patterns in the various "streams" in the Department.

The admissions process was modified substantially (and computerized) this year. Professor Thomas R. Willemain and Wren McMains helped to develop a new system for recording each M. C. P. Committee member's "scores" for the applications he/she read. These were tallied to produce a composite ranking of applicants (a measure of Committee consensus). The introduction of this ranking technique helped to depoliticize the admissions process somewhat and ensured that the best candidates could not inadvertently be missed.

The Department received 242 applications to the M. C. P. Program, 137 from men, 105 from women, 29 minority, and 32 foreign. Some 60 offers for admission to the M. C. P. Program were made. Of these offers, 32 were to women, 28 to men, 15 to minorities.

The HUD Minority Intern Program

For the past six years, the Department has received financing from the Department of Housing and Urban Development (HUD) for a Minority Intern Program within the M. C. P. program. The program provides tuition plus an annual stipend to interns, continuous fieldwork placements in public-oriented agencies, and a seminar which links the placement and the academic experience. In addition, the program has provided an informal means of fellowship among minority students.

During the past academic year, the US Department of Housing and Urban Development insisted that its funds be used to support a program for second-year students only. Consequently, the Department ran separate but parallel programs for first- and second-year M. C. P. students, with first-year students funded by the M. I. T. minority tuition program and by the College Work-Study Program. The combined number of students in both years was 24.

The intern seminars ran throughout the year. The fall seminar was designed to acquaint the students with some findings in organizational behavior which in turn would help them make the most of their placement experiences. The spring seminar was designed to help them evolve researchable questions and to construct provable arguments in the context of these placements.

All students were placed in public-oriented agencies or jobs such as the Cambridge Department of Community Affairs, the Roxbury Action Program, the Massachusetts Committee on Criminal Justice, the Southwest Corridor Coalition, and the Massachusetts Port Authority.

The intern program has been a major source of support for minority students in the professional degree program. The funding from HUD has been progressively cut back during the past three years, so that an award of \$144,000 in 1975-76 will be only \$37,500 in 1977-78. The consequences of the cutback are obviously profound in terms of the kind of support we can offer students. We hope, however, that in the coming years the funding will reach a reasonable level. Extensive national efforts to increase the funding have been undertaken by the Department in conjunction with other planning schools.

Ph. D. Program

During the past year, the doctoral program has accomplished a number of the goals outlined in the Summer Study of 1975. New administrative and evaluative procedures have succeeded in reducing the problem of the "ballooning middle" and have induced students to move more expeditiously through the program. The number of degrees given in fall, 1976 (5), spring, 1977 (5), and anticipated for fall, 1977 (7), attest to this, as does the number of those second- and third-year students who have successfully taken their General Examinations.

The program has instituted a number of requirements and review processes which seem, increasingly, to be accepted by faculty and students as a normal feature of departmental life. Among these are the first-year seminars, the General Examinations, the first-year evaluation, and the serious review of thesis proposals. The statistics/methods requirement has survived the first year. Administration, calibration, and resource difficulties aside, most first-year students seemed to feel that the requirement is worthwhile and wish only that it could be more predictably administered and more lavishly supported. Through these measures the program has become tighter and firmer and, in this respect, the quality has improved.

In spite of the fears about declining applications, in the face of a serious financial squeeze and of a very possible contraction in the job market, the quality of applications this year has been very gratifying. Also, the rate of acceptances has been unusually high. The program anticipates a first-rate entering class for fall, 1977. Eighty-two applications were received, and 31 students were admitted. Of the 31, 23 accepted admission (74 percent, as compared with an acceptance rate of 56 percent for the previous year). Two students who had been granted deferred admission plan to enroll in the fall, so that the entering class should be 25. Of the 25, 11 are women, 9 are foreign, none are US minorities.

The financial pressure on students continues. The Department's major problems are still the same: reducing tuition burden on thesis writers, increasing the level of reimbursement available to graduate students working on Institute research projects, and drawing new research and training money into the Department. Reduced financial aid and research support force students to go on leave as soon as they have completed preliminary requirements. The Department leave of absence policy, however, ensures that they will have passed generals and written an acceptable thesis proposal before they leave.

As a consequence, the program appears to be caught in a dilemma. Efforts to build a more vital student/faculty research community are stymied because students tend to leave the Department as soon as they begin to do serious research. The larger the group the less financial aid an individual student receives. This exacerbates the problem further. The research cluster initiative has not so far succeeded in significantly increasing the level of research support.

In addition to the financial issues, the program is still in the process of clarifying central areas of inquiry. These two issues -- the financial and intellectual -- are very much linked. The squeeze makes it more difficult to sustain the kinds of interactions that would help to yield a new sense of directions, and the lack of clear foci probably makes it harder to get research support.

Solutions to these problems lie in 1) re-engaging the Institute on the matter of reduced tuition for thesis students; 2) intensifying efforts to make the research clusters work better in the coming year; 3) urging faculty to bring more of their research into the Department; and 4) beginning a more productive attempt to describe the directions of inquiry which are and ought to be central to the program and to draw out their implications for subjects, examinations, and other activities.

Undergraduate Program

During the year, the Undergraduate Program Committee began an intensive review of the undergraduate curriculum. Final decisions on recommended changes will be made in fall term, 1977. These include: creation of two introductory sophomore-level subjects (majors would be required to take one); replacement of the present open choice restricted electives system with a structured choice approach (majors required to take one subject from each of four substantive areas); replacement of the senior thesis requirement with a senior project requirement in order to make clear that this terminal experience can be built around an internship or field project, in contrast with the continuing option of doing a piece of research; decreasing the number of areas of concentration to three and revising the scope and sequencing of subjects within each area. New subjects added to the undergraduate curriculum focus on the Department's commitment to strengthening its course work in environmental policy.

A major activity of the year was the planning of a national conference on "Future Directions for Urban Studies" that will take place at M.I.T. in February 1978. The event will bring together the directors of the major undergraduate urban studies programs from around the country, who are seeking to assess the effectiveness of these young programs and to discuss their future educational missions.

During the year, the undergraduate program collaborated with the Department's Ph.D. Program in an effort to improve the teaching of undergraduates by doctoral candidates. The Ph.D. Program is sponsoring a series of workshops on teaching techniques next fall. The two degree programs are seeking support for a more comprehensive program that would establish a year-long teaching seminar for doctoral students, involve faculty in supervision of doctoral students' teaching, and modestly expand the range of teaching opportunities to doctoral students.

The Department doubled the number of its faculty freshman advisors and increased its number of freshman advisees by 50 percent.

There was a significant increase in the number of UROP projects supervised during the school year within the undergraduate program. In addition, the Department sponsored a Summer Research Grants and Internships program open to all continuing M.I.T. undergraduates. The program is supporting 12 students this summer in projects that vary from an evaluation of the Massachusetts Children in Need of Services Program to internships with the Cambridge School Department, the American Institute of Planners, and the Department of Housing and Urban Development.

At the start of 1976-77 there were 47 undergraduates majoring in Urban Studies. Nine received the S. B. in February and May. Four received the S. B. and M. C. P. simultaneously through the Department's five-year Bachelor's-Master's program.

Program Groups

The Department's three substantive program groups, cutting across the degree program, continue to be Public Policy Analysis, Environmental Planning and Design, and Community and Regional Development as previously mentioned. Much discussion in the Policy Committee meetings this past year revolved around how to facilitate, organize, and promote research, both for financial reasons and reasons of educational quality. In 1975-76, the research clusters were formed in response to this problem. In 1976-77, the Policy Committee considered the potential of the program group, of the research cluster, and of the individual researcher to generate research projects. The program groups this past year did serve as a supportive structure for a certain amount of research and continued to provide impetus for the research cluster. They were not as successful, however, as certain individual faculty members on their own. It has been proposed that in 1977-78 the Department will institute "research agendas" within the program groups which, we hope, will systematically facilitate research activity.

In other ways, the program groups this year remained vital to Department life, especially in curriculum development, in the faculty search process, and in the extensive process carried out this year by the Environmental Design Program Group.

The year 1976-77 was one of consolidation for the Environmental Design Program Group. The program has settled into Room 10-485 where the proximity of most of the faculty and students has created lively interaction which has been helpful to the spirit of the program. Several new courses and some older ones were restructured to provide sequences leading from the core curriculum.

The Environmental Design Program undertook two searches in the fall: one in Environmental Design/Programming and the other in Environmental Policy/Science. The searches were widely advertised and more than 100 responses were received for both. The Environmental Policy/Science search was postponed for one year due to budget restrictions. The Environmental Design/Programming position underwent a long search procedure which resulted in the recommendation of Gary Hack for the position.

The main activity in the Public Policy Analysis Program group during 1976-77 has been the attempt to establish four "cross-cutting" courses which serve to integrate and expand the traditional discipline based knowledge of the core. In addition to the M. C. P. core curriculum, students in the Public Policy group will be required to enroll in "cross-cutting" courses which focus on problem setting, evaluation, and design and implementation. While the program groups have made great strides in creating a coherent curriculum, and in getting a core of faculty to work together, it has been less successful in attracting a group of students who identify themselves as being in the public policy analysis stream. However, of the 58 applicants offered admission into the M. C. P. Program for 1977-78, 19, or approximately one-third, specified a public policy concentration; of the 19, 11 accepted our offer of admission. In light of the characteristics of next year's class, the prospects are good for an increasingly cohesive group in public policy.

The Community and Regional Development group spans three major subareas: community development, regional development, and the urban and regional problems of developing countries. Although teaching and research activities in the three areas have proceeded with considerable liveliness and autonomy, the group has tried to encourage greater convergence in the teaching and research activities within these subareas.

Recently, tentative agreement has been reached in the need for providing a common intellectual core for all students in the group. The proposed core would supplement the M. C. P. core curriculum with a specially designed subject in Economic Development and a possible subject in Methods for Urban Studies and Planning, and Economic Development. The basic assumption underlying this view is that, following the completion of this core, students could then proceed to specialize in any of the subareas relating to community development, regional development, or the community or regional problems of the less developed countries.

Community Fellows Program

The Community Fellows Program (C.F.P.), a special non-degree program of minority community activists and government officials in the Department of Urban Studies and Planning, was inoperative during 1975-76 while a funding strategy was being implemented to give this unique mid-career program greater permanence at M. I. T. With a grant from the Rockefeller Foundation, a number of modifications were made which grew out of extensive evaluations and discussions after the 1974-75 academic year. The C.F.P. this year was viewed to be the kind of meaningful experience for which all those participating in its planning had hoped.

A new feature in the C.F.P. was its relocation into Building 7, Room 341, directly across from Department Headquarters. As hoped, the new location gave the Fellows greater access to students, faculty, and other departmental resources. The proximity to D.U.S.P. facilitated interaction between the Community Fellows, the HUD Minority Interns, and SPURS Fellows. The mutual sharing and support derived from these relationships were a distinct benefit to the operation of the Fellows Program. For the first time, the Program included Fellows from the public sector. Of the five women and four men in the program two were aides to urban mayors and two were Federal employees, one from HEW and one from the Small Business Administration. The mixture of public and private Fellows served to enhance the Program in the following ways: 1) public Fellows have a clear mandate to produce a final product to take back to their governmental unit, which infused a new purposefulness into the program; 2) the two worlds of community and bureaucracy were brought together for a meaningful exchange of perceptions, values, ideology and objectives; 3) the C.F.P. gave minority Federal employees an opportunity to use long-term Federal training monies that they would not have previously considered utilizing; 4) in the case of city government employees, the Institute made a solid connection with the City of Atlanta and the City of Newark. In the latter case, Professor Ernest Cravalho of the Department of Mechanical Engineering and Eugene Hall, General Motors scholar, traveled to Newark on two occasions to consult with Mayor Gibson's staff on energy conservation matters.

Other features of the redesigned Community Fellows Program included the creation of a two-week orientation program, which was held at M. I. T. and Mount Holyoke College August 15-31, featuring four mini-courses in Management, Economics, Leadership Development, and Communications. The purpose of it was to provide content relevant to the Fellows' interests and needs; create an intellectual and ideological framework for the Program; and to gear up the Fellows for the academic rigors in September. The most important feature of the orientation program was the weekend retreat spent at Mount Holyoke College with Fellows and their families. The opportunity for interaction early in the Program created the basis for building a support system for Fellows and their family members.

The Tuesday Evening Seminars on "Issues and Strategies of Community Development" proved to be educationally rewarding. Guest lecturers from M. I. T. and institutions in various parts of the US and presentations by the administrators, Fellows and former Fellows were part of the program. During fall term, the Seminar focused on the transformation in Third World countries with implications for minorities in the United States. The spring term was dedicated to domestic development strategies and issues presented by guests from various disciplines and fields of interest.

SPURS Program

The Special Program for Urban and Regional Studies of Developing Areas (SPURS) is completing its tenth year. The nine Fellows in the 1976-77 program came from India, Korea, Spain, Japan, Kenya, Mexico, and the Philippines.

The program started as an experiment and was funded by the Ford Foundation. This past year was the second year in which the Department absorbed the full faculty costs of the program. Financial support for the Fellows was furnished by the Ford Foundation, the Asia Foundation, the Council for International Exchange of Scholars, the Government of Mexico, the Institute of the Church in Urban-Industrial Society in association with the World Council of Churches. One of the Fellows was financed by his company, and another by an M. I. T. and SPURS fellowship.

The Program continues to provide qualified and experienced professionals with an opportunity to deepen or broaden their skills and perspectives by spending a year at M. I. T. The quality of this year's Fellows was as always very high, and they in turn rated the quality of the program as outstanding. The number of participants should have increased this year, however there was a last minute loss of funds and sponsors for some potential SPURS Fellows. Funding continues to be the most serious problem for the SPURS Program. Although there has been no lack of applications from highly qualified applicants for the academic year 1977-78, and 13 of the 16 Fellows in the coming year will have financial support from their governments, international agencies or foundations, the program is seriously restricted by the necessity to select Fellows only from those candidates who have their own financing. This problem is serious because it may exclude persons who are not intellectually or politically congenial to their governments or to the international agencies. Because this may be damaging to the SPURS Program, the program is making a special effort to raise sufficient funds to grant fellowships to four or five SPURS applicants each year. It is hoped that these efforts, if successful, will provide some support for those back-up services which are so important to the program: administrative charges, secretarial services, promotional costs, and special lectures and seminars.

The SPURS Program is an enrichment to the entire community of degree and non-degree students and it continues as an integral part of the Department to ensure recognition of the social and professional importance of the urban and regional problems in developing countries.

FACULTY

Alan Strout joined the faculty in 1976-77 as a Visiting Lecturer in rural development and development project analysis. Professors William Wheaton and Thomas Willemain were promoted from Assistant to Associate Professor.

The D. U. S. P. faculty continues to make a substantial and diverse contribution to the field of planning outside the Institute, in compensated and uncompensated public and private sectors.

Major research in the Department included Professor Lawrence Susskind's Energy Research and Development Administration (ERDA) project which was begun in June 1976 to determine the "boomtown" effects resulting from rapid development of energy facilities in small western communities. Starting this summer, under the direction of Professor Michael O'Hare, the ERDA project will shift its focus to New England to study the effects of offshore oil explorations.

Professor Karen Polenske's Multi-regional Input-Output research project, funded by the United States Department of Transportation (DOT), was completed in November 1976 and a new DOT project, Planning for Regional Economic Development, was begun under her direction.

Professor Ralph Gakenheimer is directing research on urban transportation policy in the Cairo metropolitan area, sponsored by the M. I. T. Technology Adaptation Grant. Professor Kent Colton continued his Law Enforcement Assistant Administration project studying uses of the computer by police departments.

Professors Suzann Thomas Buckle and Leonard Buckle completed an evaluation of several programs for female juvenile offenders sponsored by the Massachusetts Committee on Criminal Justice. Professor Robert Hollister began work late in spring, 1977 on a HUD sponsored project to study the Development of Public Information and Promotional Strategies in Support of Neighborhood Preservation.

M. I. T. received a \$315,000 grant from the Rockefeller Foundation for which Professor Lawrence Susskind is the principal investigator. The Environmental Impact Assessment Project is staffed by members of a number of departments including the D. U. S. P., Civil Engineering, Materials Science and Engineering, and Economics. The project will investigate the ways that public agencies can better predict the environmental impacts of large resource recovery facilities.

Paul Oppermann, former consultant, administrator, and professional urban and regional planner, donated his office library and papers to the School's library. Mr. Oppermann had been the Bemis Visiting Lecturer in metropolitan planning at M. I. T. from 1964-68. He died in March, 1977. The Oppermann Library contains examples of American planning effort across the country. These include Massachusetts state and local planning documents, and reports from the Federal Housing Administration and National Capital Housing Authority in Washington, DC.

FUTURE PROSPECTS

The year has been one in which new intellectual opportunities in public policy and environmental planning have competed with the financial crunch for departmental attention. Opportunities seem real and exciting for extending the connection in both these arenas between ourselves and other departments.

The question is whether we can make such an extension at a time when budgetary limits are as imposing as they are at present. A year ago, we indicated that we hoped not only to be successful in the scramble for research dollars but also in the quest to maintain a reasonable tone of life around the Department. While there have been some successes, this situation remains basically unchanged. We must now ask whether or not we can pursue the areas of public policy and environment while under the financial gun. We have not yet proven that we cannot. There are indications that we can; and our hope is to build on those successes while recognizing the very sobering limits imposed by the financial constraints within which we all have learned to operate.

LANGLEY C. KEYES

Laboratory of Architecture and Planning

With continued guidance from the School Council, the Laboratory of Architecture and Planning continued its multidimensional support of the research projects and programs of both departments.

In the past, the Laboratory has awarded more than \$200,000 from the Albert Farwell Bemis Fund to student and faculty projects in the School of Architecture and Planning. The intention of the School Council upon granting these awards is to further the state of the art of practice and teaching in the fields of architecture and planning. In addition to being of high quality, this year's winning proposals were promising in terms of payoff to the School as potential for further outside funding or as curriculum development.

Between \$20,000 and \$24,000 in Bemis funds were distributed by each Department to develop research clusters around faculty research. The Laboratory, however, continued to award student proposals.

Ten Bemis awards totaling \$7,405 were given to:

Patricia Bjorklund, Architecture, for a study of Union Street in San Francisco.

J. A. Chewning, Architecture, for a case study of the spatial configuration and concepts of the New England farmhouse from the 17th and 18th centuries.

Erika Franke and Brian Raila, Architecture, for the completion of a documentary investigation of communal space at a communal gathering in Montana.

Susan Henderson, Architecture, to further research to examine the impact on form of the Great Fire of London, 1666.

Dowell Myers, Urban Studies and Planning (D. U. S. P.), to develop a model of household behavior that blends population and housing variables.

Frank Miller, Architecture, to explore and develop methodologies for assessing the effect of scale changes in integrated food, energy, and waste systems.

Mark McKnew, Interdisciplinary (D. U. S. P.), to assist in the analysis of police patrol activities in the St. Louis (Missouri) Metropolitan Police Department.

Richard Polton, D. U. S. P., to add to his M. C. P. thesis on how labor unions operate as sponsors of community development projects.

Antonio Risianto, Architecture, to study indigenous design and development processes in Indonesia.

Nancy Steiber, Architecture, for an investigation of the architect's role in public housing in Amsterdam 1903-1923.

Newly funded and ongoing research projects in the Laboratory of Architecture and Planning include:

The Overlap Project, directed by Dean William Porter, with Division of Sponsored Research staff member John Klensin and D. U. S. P. lecturer Wren McMains as investigators, continued its research in interactive tools for data analysis. The \$156,000 funding is provided by the Advanced Research Projects Agency (ARPA). This year, the work focused on increased reliability, functional capability, and improved documentation for the Consistent System. Manuals of the system and of several subsystems are now available for potential users and developers. The system, designed so that all its facilities can be used together and so that it can be extended to needed areas, includes the DISCOURSE urban data management language; the JANUS data management and analysis facility for survey data; and extensive statistical, linear programming, and automatic text analysis facilities. This system is unique because it can handle many complex problems that would otherwise require special-purpose programming.

The Solar Energy Project, directed by Research Associate Timothy Johnson and sponsored by a grant of \$39,000 from the National Science Foundation. The project focused on developing variable building skins which control the amount of thermal radiation entering and leaving a building. These skins also offer the user control over the visual environment through varying proportion of transparent to opaque wall area.

The Architectural Education Study, funded by the Mellon Foundation (\$26,000) and directed by Dean Porter and Professor Julian Beinart, is laying groundwork for developing new directions in studio-based architectural education. The major topics are: the teaching and learning of architecture in schools; the developing of effectiveness in practice; and an overview of the evolving profession. The practice studies, dealing with professional development and changing professional roles and competences, are intended to provide bases for judging current teaching practice and information for planning new approaches.

The Environmental Impact Assessment Project, directed by Professor Lawrence Susskind on a \$101,000 grant from the Rockefeller Foundation, is an investigation of the ways public agencies can better predict the environmental impacts of large-scale facilities.

Urban Patterns of Change, directed by Professor Anne Vernez-Moudon, and funded primarily by the National Endowment for the Arts, started very late in the fiscal year with a volume of \$4,000. The project describes the structure and related physical elements of Victorian San Francisco and their monitored changes over the past 100 years.

Neighborhood Evolution and Decay, directed by Senior Research Scientist and D. U. S. P. Lecturer David Birch and Professor Arthur Solomon. Funded by the Department of Housing and Urban Development (HUD), it is a study of the process of neighborhood changes as the basis for developing a conceptual model of neighborhood dynamics, which can be used to estimate where and how decline and abandonment (and rejuvenation) take place.

Simulation Model for Inter-Area Migration, also funded by HUD is directed by Dr. Birch. It is a detailed analysis of the migration of people from one urban or rural area to another and of the reasons for their choice of location. This analysis will form the basis for developing a simulation model of inter-area migration. The two above projects funded by HUD have a joint budget of \$61,000.

The Innovative Resource Planning Project with a grant of \$47,000 from the National Science Foundation used operations research techniques to examine resource allocation problems in urban police, fire, and health service systems. The project, directed by Professor Richard Larson, was completed this fiscal year. The final report, which will be available in the fall as a four-volume set, will be published by Lexington Books.

The Energy Impact Project, directed by Professor Michael O'Hare and funded by the Energy Research and Development Administration (\$125,000), analyzed several issues concerning

the local impacts of large-scale energy development in the rural west. Case studies of four western states provide an understanding of the adverse conditions in energy boomtowns, their causes, and local and state governments' responses to them. These and other responses to energy development often follow from impact predictions; an analysis of prediction methods points out shortcomings of current methodologies as well as potential improvements. In response to another issue -- company alleviation of boomtowns' adverse impacts -- the project attempted to reveal the energy developer's criteria for and expectations of cooperation with communities and company compensation for second order impacts. From the empirical work, two theoretical concepts evolved: individuals, rather than governments, should receive compensation for the local "costs" imposed by energy development; the process of siting energy facilities should consider the localized social costs and should include a process for actual compensation for individuals expected to suffer because of energy development. The current work, siting energy facilities in New England, seeks to apply these concepts about compensation and siting.

The Arlington Project, a planning project with the Citizen's Involvement Committee of Arlington directed by Professor Susskind, was an effort to develop new models of broad based participation in local planning decision making. This project was completed in the 1976-77 fiscal year.

The Ottauquechee Project, funded by the Rockefeller Foundation (\$7,000) and directed by Professor O'Hare with the assistance of one undergraduate and one graduate student, was a study in Woodstock, Vermont conducted under the auspices of the Ottauquechee Regional Planning and Development Commission and dealt with problems of economic community development and land use.

For the fourth year, Professor Larson led a one-week special summer session program "Analysis of Urban Service Systems." Participants came from five countries and included administrators and academics interested in deployment of urban service systems.

The Laboratory of Architecture and Planning also served as base for the School's evolving efforts in continuing education. William Ronco, a Ph.D. candidate in Urban Studies and Planning, administered two programs: an "opening up" of the School's I.A.P. courses to practitioners in the region; and a summer program of one-week seminars. The summer courses were part of a joint program with the Harvard Graduate School of Design. There will be additional experimental programs in the coming year.

David Judelson resigned as Assistant Director of the Laboratory as of May 30, 1977. Mr. Ronco, Acting Assistant Director during the summer, is working with Dean Porter formulating some new directions for the Laboratory.

WILLIAM L. PORTER

School of Engineering

The academic year 1976-77 was characterized by the continued growth of the School of Engineering. Most striking is the increase in undergraduate enrollment by 22 percent from 1,475 in the last academic year to 1,801 for 1976-77. This growth continues, but at a more rapid rate than the increase of the two preceding years. The largest increases in undergraduate enrollment over the past three academic years occurred in the Departments of Chemical Engineering, Electrical Engineering and Computer Science, and Mechanical Engineering with about 140 students in each of these three departments. Interest among undergraduates in an engineering education at M.I.T. is continuing to grow as indicated by the fact that during the 1976-77 academic year 63 percent of all designated second-year students at M.I.T. were enrolled in the School of Engineering as compared to 55 percent during 1975-76 and 45 percent during 1974-75. Graduate enrollment continued to increase by another 3 percent (from 1,724 in 1975-76 to 1,774). The growth of the graduate program is coupled with a growth and broadening of the research program. Research volume directly administered within the School alone increased by almost 8 percent from \$23.9 million to \$28.4 million. These rapid growths have created substantial overloads on the School's faculty because the faculty size has remained constant.

Further increases in undergraduate enrollment appear certain over the next two years, with undergraduate enrollment leveling off at about 2,200 in 1979-80 and remaining at that level for a period of three to five years. As a result of the continuing enrollment growth, the Institute approved a School request that a special development fund be sought through the Leadership Campaign. This fund is designed primarily to support the increased teaching load resulting from further enrollment increases. The fund will allow the School to substantially increase its population of assistant professors, bringing that rank to a more realistic distribution among the three faculty ranks. The School has been greatly concerned that during the past decade the number of assistant professors declined by 46 percent from 131 to 70.

This special development fund will also support systematic curriculum development, particularly in the undergraduate core curriculum subjects and broader introductory graduate subjects; provide resources for the School to explore, experiment with, and implement the use of modern technology such as computers and television in the delivery of its educational programs; provide seed funds for planning and formulating larger research projects requiring cooperative efforts by groups of faculty and for related pilot projects; and provide resources for the purchase of new research equipment necessary to support the work of new assistant professors as well as present faculty moving into new fields of importance to the School.

The reports by the School's department heads and center directors address the activities of the School's individual organizational units. Here, it is appropriate to highlight some of the general trends that are of importance for the future stature of the School. These include the interface between the School and industry; the broader use of technology relating engineering and technology to the society at large, and in particular, to government and industry; and the broadening trends in the School's educational program.

The School's Relation to Industry and Practice

During the "engineering science" era, the link between the School and the practice of engineering, particularly industry, weakened, although strong relations continued with industrial research laboratories. During the past decade, as the School substantially increased its emphasis on the development of technology and its use in the engineering process, existing relations with the practicing profession and industry were greatly strengthened and new relations built. Our motivation is obvious: the School of Engineering must not only relate to the foundations of engineering, that is to the engineering sciences, but it must also relate to the practice of engineering as a profession. This transition to a more balanced perspective was accomplished through the desire of both faculty and students to research broader applied problems coupled to a growing interest in synthesis and design. During this period, faculty members and students learned to appreciate that research support for engineering does not necessarily have to come from the Federal government. They learned that such support can come directly from industry or jointly from government and industry. I would like to highlight the progress which has been made by a few examples.

Excellent working relations have been established by faculty from the School of Engineering -- working in cooperation with M. I. T. 's Energy Laboratory -- with the Electric Power Research Institute (EPRI), with utility companies in the northeastern United States, and with a number of oil companies and automotive manufacturers. These activities are described in more detail in the Report of the Director of the Energy Laboratory. Extensive contact with industry has also developed within the Polymer Processing Program led by Professor Nam P. Suh of the Department of Mechanical Engineering. This program, originally sponsored by the National Science Foundation as an experiment involving cooperation between the university, industry, and government, now has an industrially sponsored research volume exceeding \$300,000 per year. Recently, a similar program in ceramics under Professor Kent H. Bowen of the Department of Materials Science and Engineering, was established. Other examples of industrially sponsored work within the School include the pollution-control work -- based on electrofluidized beds -- led by Professor James R. Melcher of the Department of Electrical Engineering and Computer Science, EPRI support for the development and construction of a five to ten million volt-ampere super-conducting electric generator under the leadership of Professors Joseph L. Smith and Gerald L. Wilson of the Department of Mechanical Engineering with participation by the Westinghouse Corporation, and the support from the American Gas Association for research led by Professors Robert C. Reid and Kenneth A. Smith of the Department of Chemical Engineering on problems of liquified natural gas storage and handling.

The transfer of research results and new technologies developed at M. I. T. to industry and the practicing profession is rather automatic and lively in all these projects. Illustrating this, we can cite the development of "rheocasting"; the development of a technique for freezing blood cells and the application of this technology to bloodbanks; and the methodology for establishing a rational basis for optimum levels of earthquake proof resistance for constructed facilities in a given location.

In addition, School of Engineering faculty members participate extensively in the organized efforts to transfer their research results to industry through the M. I. T. Industrial Liaison Program and the advisory services of the M. I. T. Sea Grant Program.

Another important area for technology transfer and one in which spectacular growth has occurred is the area of international activities. This includes the Technology Adaptation Program led by Professor Fred Moavenzadeh of the Department of Civil Engineering which, under support from the Agency for International Development of the State Department, is actively engaged in technology adaptation and transfer in Ethiopia, and in Egypt in cooperation with the University of Cairo. Other similar activities are a port development study for

Nigeria, a crucial problem encountered by many developing nations; the development of computer models for analysis of the Vardar Axios River Basin in Yugoslavia, being done jointly with a private consulting firm; and a joint project between M. I. T. and the Jewish Agency for Israel (Ministry of Housing) on the planning and development of low-cost housing.

Another increasingly important dimension in the research done by the School's faculty and students is related to the interface between the uses of technology and societal impacts which result. Such research utilizes facts and perspectives which are vital to policy decisions and governmental actions regarding regulations. Typical examples include Professor Jack Devanney's study of the New England fisheries and the impact of a 200-mile economic zone. This study combined an analysis of fisheries resource management with an appraisal of the various economic dimensions of fisheries and the use of fish products. Professor Amedeo Odoni's new analysis applies advanced queuing theory to the problem of airport utilization and has demonstrated that the airplane handling capacity of many airports has been underestimated substantially -- negating several airport expansion plans. Dr. Nicholas Ashford of the Center for Policy Alternatives studied the safety of the workplace for the Office of Occupational Safety and Health Agency. This study covered, for the first time, the scientific, industrial, economic, and regulatory aspects of the workplace safety and has become a nationally recognized pioneering document as it provides the frame of reference within which the problem's individual facets must be discussed. Professor David Rose's pioneering study points out the health hazards associated with the various energy options now being discussed, breaking the ground for broader perspectives and systematic research in this area.

HIGHLIGHTS OF THE SCHOOL'S EDUCATIONAL PROGRAMS

During the 1976-77 academic year, faculty support for the development of new educational programs and the delivery and administration of existing programs continued. In several of these areas, there was close collaboration between the Associate Dean for Educational Programs and the Committee on Engineering Education.

Curriculum Development

Three major curricula involving students and faculty from all eight departments of the School of Engineering were established during 1976-77. To strengthen the association between the Institute and the engineering professions in industry and to provide educational opportunities that do not exist on the M. I. T. campus, the Engineering Internship Program was established. This program, which involves all the departments of the School and is supervised by a faculty steering committee, incorporates the important elements of cooperative education into a combined S. B.-S. M. program. Students supplement academic work in an M. I. T. engineering department with work in industry under the collective supervision of M. I. T. faculty and practicing professionals. The program also provides opportunities both for faculty to work more closely with engineers in industry and for industry to keep abreast of research progress on the M. I. T. campus. Students work in industry during two successive undergraduate summers and one eight-month period during their fifth year of registration. Research for the S. M. thesis is conducted in part during the latter period. Financial support for the program is derived from fees paid by participating firms; start-up funds have been sought from the Office of Education. The first work assignments will occur in summer, 1978.

A new doctoral degree program in Medical Engineering and Medical Physics was established jointly by the Schools of Engineering and Science and the Harvard-M. I. T. Division of Health

Sciences and Technology. This program, unique in medical and engineering education, combines training in clinical medicine with a strong grounding in the engineering sciences. After completion of the Master of Science in an engineering department, students engage in a year of clinical studies, a major component of the program. This is followed by doctoral research conducted in a clinical setting under the supervision of engineering and medical faculty in hospitals affiliated with Harvard Medical School. Graduates of the program will be engaged in medical research on problems of important clinical significance. The first class will enter in fall, 1978 following the development of subject syllabi.

In response to the stress placed on the world's mineral resources by the ever-increasing crisis in energy production, the faculty of the School, in collaboration with faculty of the Schools of Science, Humanities and Social Science, and Management, have created a new program of graduate study in Mineral Resources Engineering and Management. The program, structured under existing degree programs in the School, offers four options -- exploration, extraction, processing, and resource management -- and is designed to coordinate the studies of participating students and to facilitate new research efforts of the faculty. The first students will enroll in fall, 1977.

The Innovation Center, presently in its fourth year of operation under a five-year grant from the National Science Foundation, offers two educational programs dealing with the innovation process: a program of formal, classroom instruction comprised of five subject offerings for first-year undergraduates through advanced graduate students, and a less structured program, the Innovation Coop, that provides hands-on experience for novice innovators. This year the intellectual base of the program was strengthened by a collaborative effort of the participating faculty resulting in the writing of three new textbooks on the methodology of innovation, invention, and entrepreneurship. The books are scheduled for release in early 1978. Efforts are presently under way to develop financial resources to support classroom instruction after the termination of the National Science Foundation grant. A plan has also been formulated for the independent funding of the Innovation Coop. This plan provides incentives for faculty and student participation in the Innovation Center without imposing on the already heavily stressed resources of the School.

During the past academic year, a group of faculty concerned with the development of a curriculum in the broad area of safety, particularly hazard analysis and risk-benefit analysis, was convened. These faculty from both within and without the School share a common interest in the way the application of technology affects the safety and well-being of its users. They are interested in both the technical and policy aspects of the problem and in the education of engineers who will in the future bear a greater portion of the responsibility for the social impact of technology. Because of its multidisciplinary nature, this problem area can be treated most effectively at the School level. Present efforts in this area are devoted to curriculum development for a course of study at the beginning graduate level. Several approaches are being considered: 1) imbedding these considerations in existing subjects; 2) developing an appropriate series of seminars; 3) developing specialized subjects; 4) developing summer programs or short subjects for industry; and 5) combinations of the above.

With the support of this office, a group of faculty drawn from all departments in the School have developed a new undergraduate subject in computer modeling of physical systems. This subject, offered during spring term, uses the common theme of computer modeling to demonstrate the similarities and differences of the various fields of engineering. This subject was of particular interest to undesignated students who are trying to select one of the engineering fields as an area of concentrated study.

Resource Development

Efforts continued to develop support for both undergraduate and graduate students. The General Motors Scholarship program, begun in 1975-76, was expanded from 10 to 19 students. This program provides full tuition and fees and summer work for engineering students beginning in the sophomore year. Research support for undergraduate students was again provided through funds from the Clapp and Poliak Foundation. These projects stressed design engineering and resulted in a wide variety of new engineering designs, some of which, such as a new design for a record turntable, are being further developed for commercial production. An association with the Weyerhaeuser Corporation, initiated in 1975-76, was strengthened further. The current Weyerhaeuser Fellow, Mark Proulx of the Department of Mechanical Engineering, spent a portion of the Independent Activities Period at the Weyerhaeuser operations in Tacoma, Washington, identifying possible research activities that would lend themselves to thesis and design projects in that department. Mr. Proulx will continue as the Weyerhaeuser Fellow for 1977-78.

Special Programs for Minority and Pre-College Students

During summer, 1976, 40 minority high school students from the Eastern United States participated in the program, Minority Introduction to Engineering (M.I.T.E.) designed to increase the awareness of minority students of the professional opportunities in engineering. Sponsored by the Engineers Council for Professional Development, the program describes the various career options in engineering and provides participants with an introduction to the social and academic aspects of college life. A major portion of the two-week program was devoted to a design experience in which these students worked under supervision of the M.I.T. faculty to meet a set of specifications with limited material, financial, and time resources. Twenty-six of the participants had completed the junior year in high school and 14 had completed the sophomore year. Eight of the 26 were admitted to M.I.T. for fall, 1977 and seven will be attending. The M.I.T.E. Program will also be conducted in summer, 1977 with major support provided by the Office of the President and the Chancellor.

Another program for high-school students, Work in Technology and Science (W.I.T.S.), was conducted by M.I.T. engineering faculty during the academic year. This program, a collaborative effort between the School of Engineering and the Wellesley School System, introduced the world of engineering design to 13 ninth-grade students. Lectures by M.I.T. faculty on topics of structural mechanics were supplemented by laboratory work in which students designed, constructed, and tested model bridges from a kit of materials. An M.I.T. plaque of achievement was awarded to the student with the best structural design, and faculty and students from the program presented a seminar on their experiences to other participants. This design program will be expanded further during academic year 1977-78.

Further efforts were devoted to increasing the number of minorities in the graduate programs of the School. A program was established with the Draper Laboratory to provide summer employment for undergraduates from colleges with large minority enrollments. Upon completion of their undergraduate studies, those students admitted to graduate programs in the School of Engineering at M.I.T. would be guaranteed research assistantships in Draper Laboratory. The program is designed to accommodate 10 new students per year; the first group will enter in summer, 1978.

Methods of Instruction

Attention also was devoted during the academic year to the development of new methods of instruction. The use of television in teaching, particularly tutored video instruction (T.V.I.),

was encouraged. Experiments also were conducted in which quiz review sessions were held in the evening hours, and broadcast on the M. I. T. cable network and taped. These tapes were placed on reserve in the Engineering Library for later viewing. Student response was quite favorable; most considered the format well worth the effort and expense. They were able to review the tapes at their leisure and as many times as they felt appropriate for their needs. This method of instruction warrants further attention and a more systematic review, particularly with the support of the Division for Study and Research in Education. A new film on engineering design was produced in the Department of Mechanical Engineering with the support of the Office of the Associate Dean. This film, describing the design experience of subject 2.70 under the direction of Professor Woodie Flowers, holder of a Class of 1922 Career Development Professorship, has been shown to widely diverse groups ranging from high-school students to alumni. In all cases, the response to this new mode of instruction has been enthusiastic. In fact, this mode serves as the basis for pre-college programs conducted by the School of Engineering.

In a parallel effort, attempts are being made to coordinate the use of case studies in teaching several subjects such as engineering design. This method has been used successfully in the Department of Civil Engineering by Professor James M. Becker and in teaching engineering management in the Department of Mechanical Engineering by Dr. Robert Lund. The case study method as used at M. I. T. often differs significantly from that used in other engineering curricula in that students generate much of the case material themselves. Students first use cases generated by previous students in the subject and then generate their own material. This process ensures an active file of case material, but more importantly requires students to be in the "field" dealing with practicing professionals.

At the interface between the humanities and engineering, the Office of the Dean provided partial support for four scholars under the aegis of a grant from the Mellon Foundation: Professor Joseph Weizenbaum of the Department of Electrical Engineering and Computer Science, Professor Leon Trilling of the Department of Aeronautics and Astronautics, Dr. Janet Rossow of the Department of Civil Engineering, and Dr. David Noble of the Technology and Policy Program. All of these scholars were working on the humanistic view of their particular fields of expertise, Professor Weizenbaum on the social impact of computers, Professor Trilling on the impact of the technology of weapons and weapon systems on society, Dr. Rossow on the social ramifications of various methods of construction, and Dr. Noble on the broader aspects of the social consequences of technology. The work of Dr. Noble in particular has had a significant positive influence on the development of the proseminar in the Technology and Policy Program.

The Committee on Engineering Education (C. E. E.)

The Committee on Engineering Education (C. E. E.) was created in fall, 1975 as an outgrowth of the School-wide self-appraisal project. At the completion of the self-appraisal it was apparent from many perspectives that a broad-based, major review of the entire educational program in the School should be undertaken. The particular factors that made the review timely included external pressures such as the changing role of engineers in society, the changing character and direction of research support, and changing social and political environment in which engineering is practiced. Internal pressures were, and are, also important. These included the continued financial constraints, the increasing student interest in careers in engineering, and the widely felt need on the part of the faculty to keep the educational program responsive to our students' future professional lives.

The C. E. E. was charged with the responsibilities of developing and recommending educational policies for the School and also providing leadership in creating new educational initiatives. The Committee functions with a broader perspective than curriculum committees within each

department. As such its concerns are those of an interdepartmental, academic nature and the Committee operates in the interspace between departmental committees and standing committees of the faculty as a whole.

In October 1976 the C. E. E. issued a comprehensive progress report to the faculty. The report incorporated Committee efforts regarding School-wide policy and discussed the issues for which specific initiatives were being contemplated. The Committee invested considerable effort in formulating a statement of Goals for Engineering Education at M. I. T. which provides the foundation upon which our programs are based. These goals incorporate the commitments which our educational programs have to our students, the society at-large, the engineering professions, and to the Institute.

Based upon these goals the Committee next considered the appropriate components the undergraduate and graduate engineering education should contain. These components are described in terms of both the academic program and the academic environment in which our students learn. Together these components serve as a set of guidelines for future planning of educational reforms and/or new initiatives.

The Committee has tried to keep in close contact with the faculty, both to learn of their opinions and to keep them informed. Thus we have operated in a mode that includes frequent open meetings. However the Committee's most important vehicle for communication has been a newsletter which is issued frequently and describes the direction and substance of the Committee's work.

As a result of the Committee's discussions, it is apparent that there are subjects, at both the undergraduate and graduate level, which are of interest to more than one department. However in many instances, it is difficult for individual departments to incorporate such subjects in their own programs because of personnel and budget limitations. Yet the educational objectives of the School would be well served by making them available to our students. Examples of such subjects include: service subjects to students, such as computer programming; subjects of common interest but not central to a department program, such as entrepreneurship or innovation; subjects that integrate knowledge from several disciplines and induce a frame of mind for synthesizing this knowledge, such as design subjects; and subjects that interface between engineering and other professions, such as economics, law, and management.

The C. E. E. has obtained permission from the appropriate faculty committees to conduct a three-year experiment in creating, offering, and evaluating subjects which will be School-wide. The subjects will be listed in a separate portion of the catalogue, some financial support will be made available via the Dean's Office, and they will be very carefully evaluated with respect to their impact and usefulness to the students.

Most of the engineering sciences such as thermodynamics, structural mechanics, and fluid dynamics are part of the core curriculum in most departments. Although there are gaps and overlaps in the subject offerings at each level, each department has a unique perspective on the discipline and quite naturally desires to retain its own special version. The C. E. E. has studied the question of how interdepartmental coordination and planning can be carried out in certain of the disciplines. We have begun to bring together faculty from different engineering departments to form an "area committee." These committees are ad hoc in nature and meet to consider questions of scheduling of similar subjects to provide students with optimum flexibility, improving the advisory system to students in the area, and considering whether or not the collection of subjects is complete and, if not, recommending curriculum development directions.

Another important activity of these area committees is to develop School-wide undergraduate laboratories in their area. Over the years the laboratory facilities have deteriorated in almost all undergraduate labs. The cost of acquiring and maintaining up-to-date equipment is too high for most departments to support excellent undergraduate labs. We believe the area committees can bring together the expertise to plan, staff, operate, and maintain inter-departmental labs for the benefit of all departments.

There is a growing interest on the part of women graduates of liberal arts colleges to seek graduate education in engineering. Most of these students are undergraduate science majors, and going on to graduate school in science is not a difficult problem. However, it is very difficult for women to make the transfer into engineering graduate school.

The C. E. E. has met with Dean Emily Wick of Mount Holyoke College to discuss that problem and possible means of dealing with it. As a result, M. I. T. and Mount Holyoke are preparing a proposal for support for a special summer program to introduce women from liberal arts schools to engineering education and engineering practice.

The program will be of eight weeks duration and will include an option of one of several introductory engineering science subjects, a special subject based on a design concept to illustrate the interrelationships in engineering practice, and a laboratory experience in one of the research laboratories at M. I. T. The participants will gain sufficient experience to help make a better-informed decision about the possibilities of pursuing graduate study in engineering, and what electives in their remaining undergraduate years would be most helpful to their preparation.

In addition to the special program the C. E. E. has met with representatives from each department in the School to discuss problems of students attempting to enter graduate school from a liberal arts undergraduate program. As a result of these discussions, a pamphlet will be produced and mailed to prospective students. It will include required subjects for admission, recommended subjects for admission, descriptions of programs leading to the Master of Science, and people at M. I. T. to contact for advice.

FACULTY

During the past year, many of the School's faculty received special recognition for their professional accomplishments.

Institute Professor Ascher H. Shapiro of the Department of Mechanical Engineering was the recipient of the Lamme Award, the American Society of Engineering Education's highest honor. This award is bestowed for "excellence in teaching, contributions to the art of teaching, to research and technical literature, to the advancement of the profession, and to engineering college administration."

Professor Ali S. Argon of the Department of Mechanical Engineering received the Charles Russ Richards Memorial Award of the American Society of Mechanical Engineers/Pi Tau Sigma, which is awarded each year to an "outstanding mechanical engineer within 20 years of graduation."

Professor Robert W. Mann, Whitaker Professor of Biomedical Engineering in the Department of Mechanical Engineering, was named Outstanding Bioengineer for the Year 1977. This was the American Society of Mechanical Engineers' Bioengineering Division's first such award for "recognized distinguished engineering achievements in developing the field of bioengineering

with the mechanical engineering profession and for his successful synthesis of engineering and medicine to aid the physically handicapped. "

Professor Robert M. Fano, Ford Professor of Engineering in the Department of Electrical Engineering and Computer Science, received the Education Medal of the Institute of Electrical and Electronic Engineers.

Professor John W. Cahn of the Department of Materials Science and Engineering received the Acta Metallurgica Gold Medal, the most prestigious international award in physical metallurgy.

Professor Norman C. Rasmussen, Head of the Department of Nuclear Engineering, received the Distinguished Service Award of the Nuclear Regulatory Commission.

Professors Rasmussen, Stephen H. Crandell (Department of Mechanical Engineering), Walter S. Owen (Department of Materials Science and Engineering), Ronald F. Probst (Department of Mechanical Engineering), John G. Trump (Department of Electrical Engineering and Computer Science), Arthur R. von Hippel (Department of Electrical Engineering and Computer Science) were elected to membership in the National Academy of Engineering.

Professor Kenneth N. Stevens of the Department of Electrical Engineering and Computer Science, internationally recognized for his outstanding research in the field of speech communications, was appointed the Clarence Joseph LeBel Professor of Electrical Engineering.

Professor Ernest G. Cravalho, Professor of Mechanical Engineering and Associate Dean of the School of Engineering for Educational Programs, and Associate Professor Roger G. Mark of the Department of Electrical Engineering and Computer Science were jointly appointed to the newly established Matsushita Professorship of Engineering and Medicine. This professorship strives to create a greater, economically sound and wiser use of technology to achieve urgently needed advances in health care and medicine.

Faculty members from the School of Engineering who retired this past year were Professor Michael B. Bever of the Department of Materials Science and Engineering, after 37 years of service, and Professor J. Francis Reintjes of the Department of Electrical Engineering and Computer Science, after 30 years of service to the Institute. Both will continue their research activities on a part-time basis.

During the past year, Professor Kenneth A. Smith assumed the responsibilities as Acting Department Head for the Department of Chemical Engineering while a nationwide search was conducted for a new department head. Professor Smith led the department through a challenging period when undergraduate enrollment grew substantially, sponsored research increased significantly, a new practice school station was established, and active recruitment resulted in addition of four new faculty members to the department. The search has now culminated with the appointment of Dr. James Wei, a distinguished chemical engineer who is widely noted for his pioneering research, industrial accomplishments, and academic contributions to the chemical engineering profession. Professor Wei has also been named Warren K. Lewis Professor of Chemical Engineering.

ALFRED H. KEIL

Department of Aeronautics and Astronautics

The past year has been one of growth and redirection for the Department in both teaching and research. Interesting new opportunities are developing for aerospace as the nation wrestles with its problems of energy and transportation. The Department is organizing its activities so as to remain in the forefront of the technological advances being stimulated by these problems and to train students who will be able to contribute effectively to their solution.

For example, the fuel efficient aircraft impacts all of our disciplines, requiring advanced structural concepts such as composites, improved propulsion systems, a higher degree of automation resulting in improved control and reduced fatigue loading, and improved aerodynamics resulting from more powerful computational techniques. In all these areas active research and, where appropriate, teaching is under way.

The incipient energy crisis also has stirred interest in advanced energy concepts such as the the Satellite Solar Power System, improved gas turbines for stationary power plants, magnetohydrodynamics, wind turbines and wave turbines. The Department is actively involved in research and engineering in these areas.

Undergraduate enrollment continues to grow, with entering sophomores up from 28 to 46. Total undergraduate fall enrollments for the past four years show the following pattern:

1973-74	64
1974-75	58
1975-76	67
1976-77	92

Graduate school enrollment shows the following pattern:

1973-74	134
1974-75	133
1975-76	163
1976-77	153

The slight downward trend resulted from the low nationwide enrollment in aerospace in all schools during the past several years. The supply of qualified graduates may well remain below the number of opportunities which the Department has to offer in research assistantships during the next few years. Hopefully, as the new and interesting thrusts of aerospace become more generally known, enrollment will increase throughout the nation, increasing the pool of possible graduate students.

Total research volume in the Department has continued its upward trend, with the 1977 forecast of \$3.6 million compared to \$3.3 million in 1975. The Department continues to generate a substantial amount of research administered by the special laboratories such as the Transportation Center, the Energy Laboratory, and the Research Laboratory of Electronics. It is estimated that the true volume generated by Department faculty in 1977 will be more than \$4.4 million.

The increased enrollment and increased research of the Department are being handled by a continually shrinking faculty. The active faculty is now less than 70 percent of the 1969

level, at which time the total research volume was \$2.6 million, undergraduate enrollment was 172, and graduate enrollment was 184. In addition the faculty is now approaching 84 percent tenured. The Department seriously feels the need for new, young faculty members who can share the burden of research and teaching and be available to follow new thrusts in research as these may develop.

The Department encourages undergraduate students to obtain hands-on experience in several engineering projects in the Department and through the Undergraduate Research Opportunities Program (UROP). Twenty-six students are involved in the UROP program and seven students on the man-powered aircraft. Four students work on the penultimate sailplane program. The Innovation Coop, a lively Institute-wide experiment in creativity in entrepreneurship, involves several of the Department's faculty.

The Department made the following awards to its student body: Henry Webb Salisbury Award, Judith Carol Thompson; James Means Memorial Prize, Peter David McQuade and Kenneth Chinien Sun; Luis de Florez Awards, Guido Haymann, Alexey Vladamir Orlovsky, and John Elbert Jaynes.

As usual the very active Student Chapter of the American Institute of Aeronautics and Astronautics in the Department provided valuable assistance in organizing student activities and in encouraging student participation in the Northeast Regional Conference, where Karen Knoll and Ken Sun won awards in the oral presentation of papers, Ken Sun receiving an additional award in the written competition.

The departmental teaching and research activities may best be detailed by the following brief descriptions of the various divisions of instruction together with the 12 associated research laboratories. Particular emphasis will be placed on new thrusts which have been developing during the past year.

Instrumentation, Guidance and Control

This division continues to enroll the largest number of graduate students, 40 percent of the total. A large number (45 percent) of these students are supported by Draper Laboratory fellowships. The association of the Department with the Draper Laboratory continues to be close and fruitful. It has become apparent, however, that there is need for increased departmental laboratory activity in this division in order to accommodate, for example, foreign students who are not eligible for Draper Laboratory fellowships.

It is also the feeling of the Department that new and important developments are forthcoming as experience with modern control systems and microprocessors indicates that their reliability is high enough to warrant their being used in primary control systems in aircraft, as they have been for many years in spacecraft. The Division has therefore developed several new research programs including the application of new CCD (charge coupled) devices to optical image processing, the detection of component failures in control systems, and the development of optimum control utilization (harmonious control) for aircraft.

The Department has also initiated a new Avionics option in its curriculum which has attracted several students. Its success has encouraged consideration of a Master's program in Avionics, which if implemented may also prove attractive to several government agencies.

A new velocity measuring technique, laser streak velocimetry, has been developed for visualizing two-dimensional flows in gases. This technique is particularly useful for measuring the velocity profile in a boundary layer, for mapping unsteady flows such as vortex shedding at low Reynolds number past a circular cylinder, and for visualizing the complex flow

of a delta wing at high angle of attack. A new concept for laser gyroscopes also has been developed based on the use of a passive ring resonator as a rotation sensing element and an external laser for measuring the difference between the clockwise and counterclockwise lengths of the resonator. The laboratory has continued its work on molecular beam stabilized multiwatt argon lasers, and frequency reproducibility of 1.5×10^{-12} has been demonstrated, the best yet achieved in the visible region of the spectrum. The frequency jitter in commercial cw dye lasers has been reduced by a factor of 1,000 by the use of wide-band feedback loops. Ultra high resolution spectroscopy has shown the hyperfine structure of I_2 to unprecedentedly high precision.

Research on the vestibular function in posture control has culminated in the acceptance of a proposal for vestibular experiments to be flown on Spacelab. This research will be of primary importance in determining the ability of humans to adapt to zero gravity and has particular implications for the short-term space traveler. Work is continuing on the transduction mechanisms in the semicircular canals and laterally aligned organs, which has resulted in a major change in the traditional view of semicircular canal cupola motion. Work is continuing on the development of remedial math programs in area schools based on a new strategy for presenting arithmetic and on the etiology of ski accidents which will lead to better design of ski bindings.

Finally, a new research program has been initiated on airborne investigation of thunderstorm electric currents and convective structures. Efforts also are being made to revitalize inertial guidance activities in the department through the development of an inertial test facility.

Structures, Materials and Aeroelasticity

One of the most important techniques for improving air transportation efficiency is to reduce the structural weight of the vehicle and increase its fatigue tolerance. The inert weight is approximately three times the payload; hence the potential for improving fuel efficiency in terms of passenger miles per pound of fuel by reducing the structural weight is very great indeed. This division has put a major effort into understanding the promising new area of structural design involving filamentary composites and in studying the problem of crack growth with a view to a better understanding of fatigue in both conventional and bi-material structures. This effort is about to culminate in a \$1 million five-year program from the Air Force Materials Laboratory and the Office of Scientific Research for the study of composite structures and their fabrication.

Much of this research depends on sophisticated applications of finite element theory pioneered by the members of this division. In particular the hybrid stress method has been extended to reduce the constraint conditions in applications of plate and shell analysis to nearly incompressible materials and to develop an efficient three-dimensional crack element. Two finite element computer codes have been developed for analyzing single-layer and multilayer multimaterial rings which may be used for studying the impact loads on such material when used as a container for fragments resulting from engine rotor burst. This work has been extended to an understanding of the structural integrity of metal panel structures which house power plant equipment and may be subject to impact from external bodies. These techniques have also been applied to the problem of crashworthiness of rail tank cars. Finite element computer code applications have been made to the stress analysis of machine tools and for the static stress analysis of an urban rail car resistor support fixture. A general study of the stress cycle model problem led to a completely new formulation of random load crack growth predictions based upon modern (Kalman filtering) estimation theory.

Research has been conducted on the dynamic response and control of helicopters and tilt-wing aircraft and of large wind turbine rotors to gusts and other loads. Methods are being developed for alleviating such effects through closed-loop control systems.

Data acquisition systems have been designed, fabricated, and installed on several large buildings to obtain on-site measurements of wind-induced pressure loadings, accelerations, and window deflections. These results are correlated with wind tunnel tests and used as a means for providing a rational design of large structures in the presence of wind loads.

Energy Conversion and Propulsion

Work in this division, which covers a wide range of disciplines including fluid mechanics, thermodynamics, and structures, has had as one of its primary aims a better understanding of the gas turbine performance which would lead eventually to reduced fuel consumption and weight, important factors in the fuel efficient aircraft.

The work carried out in this laboratory is best characterized as research on dynamic energy conversion. It covers a wide range of disciplines and devices. The former include fluid mechanics, solid mechanics, plasma physics, heat transfer, and numerical computation of transonic flows. Motivation stems from applications to gas turbines, both aircraft and stationary MHD power generators, high powered lasers, and fusion reactors.

The research programs on cooled turbines for aircraft engines, and on compressors are particularly expansive at present. As a result of its basic research on computation of three-dimensional transonic compressor flows, and of the time resolved flow measurements and flow visualization carried out in the Blowdown Compressor Facility, the Laboratory is now using these methods to evaluate two state-of-the-art compressor stages for NASA and the USAF. As part of this program a minicomputer for dedicated computational fluid dynamics has been acquired and will be used to generate the three-dimensional solutions for the compressors. Research in this field addresses the key problems of cooling optimization in very high temperature turbines, increased work per stage, the effects of three-dimensional flows on heat transfer characteristics, and the effects of unsteady flow on pressure losses and heat transfer.

In addition, research has continued on MHD power generation and significant contributions were made particularly on coal devolatilization, combustor modeling, on a new type of electrode, the spinel electrode, on interelectrode breakdown, on plasma properties with nonuniformities, and on the disk generator. Under the US-USSR program, the joint study of electrode breakdown characteristics has proceeded satisfactorily.

Mechanics and Physics of Fluids

This division is conducting a complete review of its basic course structure. In particular a new basic subject, 16.035 Fluid Mechanics, is now required of all graduate students in the division and has attracted a healthy enrollment from other departments. There was concern that the course program of many graduate students in fluid mechanics is too narrow, preparing the student primarily to do thesis research. Consequently an additional required subject in gas dynamics in slightly modified form will be required of all doctoral candidates. The offerings in viscous flow and heat transfer are being redesigned. Thesis committees also are being requested to ensure that the course program of each student is sufficiently broad to enable him or her to work intelligently in many areas of fluid mechanics. Interaction with other departments has been strongly encouraged, resulting in cooperative research and teaching efforts with the Departments of Mathematics, Mechanical Engineering, and Ocean Engineering.

The important developing area of computational fluid mechanics is being pursued in several research programs and a subject in this area will be offered jointly with the Propulsion division.

Major advances have been made in the understanding of the structure of boundary-layer turbulence, and these advances have been widely acclaimed. Research also is being conducted on wind generation of water waves and on the stability of vortex rings. Active research projects treat unsteady aerodynamics relating to noise from blade vortex interaction at high speeds on helicopter rotors which will result in a better understanding of this important problem. Rotor noise research is also concerned with noise generated by a rotor in turbulent flow.

Continued research on gas surface interaction, after a brief respite because of funding problems, has resulted in the development of several new programs of great interest on the physics of adsorption, particularly the kinetics of droplet or crystal growth in homogeneous nucleation, with a consequent model for the size, distribution, and growth of ice and aerosol particles in the atmosphere.

In hypersonic aerodynamics, research has focused on the flow field evaluation for off-design waverider configurations with particular emphasis on the effect of slightly detached shock conditions on the possible degradation of the ideal performance. Recent experiments are directed to mapping the wake of wire supported models and the development of techniques for magnetically suspending these shaped bodies. Investigations have been made of the effects of inhomogeneity on the propagation of acoustic waves, which establish some limitations on currently used kinetic theory of dilute gas modeling of the effects of random inhomogeneities on wave propagation.

The magnetic wind tunnel balance system is currently being used to study the origin of the magnus side forces on spinning bodies. Two feasibility studies are under way on improvements of the balance involving application of a microcomputer for automatic control in the servo system and on the use of superconducting coils.

Finally, in a somewhat unrelated area of fluid mechanics, a new project in biomedical engineering in cooperation with Boston's Children's Hospital will investigate the use of pneumatic pressure to provide quantitative application and measurement of forces in the Boston Scoliosis Orthosis, a device to assist individuals who have a lateral deviation of the spine.

Aeronautical and Astronautical Systems

Activities in this division may be grouped into Space Systems and Air Transportation for the purpose of discussing teaching and research efforts.

There is continuing difficulty in finding sponsorship for research programs in support of the active teaching programs in the area of Space Systems engineering. The Department is currently studying the problems of large space structures and the optimum means of designing and assembling these for minimum total cost and maximum effectiveness. The immediate application is for satellite solar power systems, which promise to be an almost ideal solution to the developing energy crisis. At the present time, insufficient information exists to allow a definite prediction of their costs. Current research is aimed at providing such understanding in collaboration with industry investigators.

This year the Advanced Space Systems Engineering course has studied the problem of space habitats and produced a report which has had wide distribution with a continuing demand for copies. This represents one of the most complete and definitive studies of the potentials of space colonization.

In the area of Air Transportation Systems major effort has been devoted to the study of airline regulatory policies and the possible impact of current proposals for deregulation. Work also

is continuing on the development of computer algorithms for solving large-scale network problems which appear in transportation. This work is of value both for solving airline schedule control problems as schedule disruptions occur and for solving railroad yard work assignment, train routing, and makeup problems.

An important new area of effort is in developing air travel forecasting techniques involving the development of a series of econometric demand models for domestic passenger travel between city pairs and the impact of changing technology on this demand.

Studies of the problems of short-haul air transportation are continuing. The parameters which would control the development of an urban and suburban air transportation system to relieve ground congestion in heavily built-up areas have been defined. It has been established that for a mature system, common carrier air transportation costs of the same order as existing ground systems are possible, eventually without the need for subsidy.

A continuing study aimed at the development of improved aircraft navigation and guidance systems for air traffic control has concentrated on general aviation applications, including a study of Omega and Loran C navigation systems using a microprocessor and cathode ray tube for display. Cockpit simulator work has focused on the development of an airborne traffic situation display which, with low work load and in the face of varying winds and noisy radar information, has shown amazing potential precision. Future work will be carried out on flight command systems for aircraft with complete six degree of freedom control.

Valuable work has been conducted on the problem of aircraft capacity and delay at airports which has resulted in the development of several analytical computer programs. A sole source contract from the Federal Aviation Administration (FAA) has been received to compare these methods with existing ones and apply them to airport studies in this country.

FACULTY

Professors Eugene Covert and Harold Wachman chaired the Undergraduate Committee and the Graduate Committee respectively. Professor Philip Whitaker continues to supervise the Engineers degree program while serving as Chairman of the Freshman Orientation Committee. Professor Winston Markey chaired the interdepartmental doctoral program in Instrumentation and the Doctoral Committee. He also organized an interesting series of departmental seminars which were taken for credit by 21 students. Of particular interest was the series on Space Utilization which attracted several outstanding speakers and will appear as a bound report.

Professor Jack Kerrebrock chaired the Institute Committee on Discipline, Professor Covert continued to chair the Committee on Curricula, and Professor James Mar chaired the Athletic Board.

The Department was particularly fortunate to have as Hunsaker Professor Dr. Gerard K. O'Neill of Princeton University, who in addition to contributing lectures in several course subjects and supervising graduate research programs, presented an outstanding seminar series entitled "Space Flight Via Maxwell's Equations." The Department looks forward to a continued association with Professor O'Neill.

Professor Kerrebrock was appointed Richard Cockburn Maclaurin Professor of Aeronautics and Astronautics in recognition of his outstanding contributions to the School's activities in Propulsion. Professor Mar was elected a Fellow of the American Institute of Aeronautics and

Astronautics (AIAA). Professor Shaoul Ezekiel was appointed Fellow of the Optical Society of America. Professor Wesley Harris received the 1977 Award for Excellence in Engineering by the National Consortium for Black Professional Development, and Professor Amedeo Odoni received the 1977 Teaching Award from the Graduate Student Council.

Members of the faculty were particularly active on various government advisory boards. Professor Kerrebrock chaired the Science and Technology Advisory Group of the Air Force Scientific Advisory Board and together with Professor Sheila Widnall served on the Aeronautics and Space Engineering Board of the National Academy of Engineering. Professor Covert is the Chairman of a cross matrix panel for the Air Force Scientific Advisory Board. Professor John McCarthy chaired the Division Advisory Group of the Air Force Systems Command, and Professor Widnall chaired the AIAA Sperry Award Committee and the Society of Women Engineers Outstanding Achievement Award Committee. Several other members of the Department served on various panels and advisory committees of the Federal government and professional organizations.

Professors Lawrence Young and Charles Oman continue to make major contributions to the Division of Health Sciences and Technology. Professor Jean Louis, as Associate Director of the Energy Laboratory, has initiated several new programs in fossil fuels utilization.

The Department had the pleasure of welcoming Dr. Alexander Efremov of the Moscow Aviation Institute as an IREX Exchange Scientist, who provided useful interchange with the USSR on research in man-machine interaction.

R. H. MILLER

Department of Chemical Engineering

During the past year expanded research volume and increased enrollment in the undergraduate and graduate programs have maintained a high level of department activity and placed heavy demands on the faculty. Professor Kenneth A. Smith provided leadership for the Department as Acting Head while the search continued for a permanent department head. This search process provided a period of reassessment for the Department and extensive discussions were held relative to the conflicting demands imposed by peer evaluation, the master's degree program, the Practice School program, and other factors. More generally, the pressures are those of engineering science versus the practice of engineering. Traditionally, the strength of the Department has been in its ability to bring the best of science and technology to bear on the most relevant of real problems. The discussions led to a reaffirmation that such a course continues to be both possible and desirable, and to the naming of Professor James Wei as Department Head-designate. Professor Wei is currently Allan P. Colburn Professor of Chemical Engineering at the University of Delaware and we look forward to the leadership which he will provide.

Undergraduate Program

There was a significant enrollment increase in the undergraduate program again this year, and a combination of lecture presentations and multiple sections for recitations was instituted for the core subjects. This procedure assures the continued delivery of high quality education, but minimizes the impact of large classes on faculty time and costs. The Department faculty proved to be responsive.

The following table shows the recent trend in chemical engineering enrollment.

	<u>Undergraduate Enrollment</u>			
	<u>1973-74</u>	<u>1974-75</u>	<u>1975-76</u>	<u>1976-77</u>
Sophomore	31	47	79	102
Junior	37	39	60	97
Senior	39	38	45	51*

*Does not include students in the five-year program who have transferred to the graduate school.

The current high demand for chemical engineers, resulting in part from national energy and environmental problems, will absorb the graduates of these large classes in the immediate future. However, if further increases in enrollment should occur, some restructuring of Department priorities may be required.

The introductory core subjects in chemical engineering, 10.13 Mass and Energy Processing and 10.14 Thermodynamics, continued to attract students from other disciplines. Supported by the Research Initiation and Support (RIAS) project, Professor Robert C. Armstrong has developed a Polymer Rheology Laboratory which complements the present 10.67 Polymer Science Laboratory. In recognition of the Department's strong interaction with industry and of the desirability of exposing undergraduate engineering students to real problems, Professors Lawrence B. Evans and Jack B. Howard arranged for industrial consultants to participate with student groups in a number of projects drawn from local companies in the 10.26 Chemical Engineering Projects Laboratory.

The Graduate Program

Enrollment in the graduate program increased to 181 full-time students of whom 49 were doctoral candidates. Reversing a trend in recent years, there was also an increase in applicants for the doctoral program. However, industry continues to attract most of our graduate students at the S. M. level. The following table shows graduate enrollment for recent years.

	<u>Graduate Enrollment</u>			
	<u>1973-74</u>	<u>1974-75</u>	<u>1975-76</u>	<u>1976-77</u>
Total Graduate Students	148	149	163	181
Doctoral Candidates	47	49	46	49

The Practice School continues to be an important and popular part of our graduate program. A Cambridge Station, operated during the year with the cooperation of Artisan Industries of Waltham and Dynatech R/D Company of Cambridge, provided a temporary replacement for the American Cyanamid Company Station at Bound Brook, New Jersey which closed last year. These arrangements, together with the program at the Oak Ridge National Laboratory, Oak Ridge, Tennessee, provided practice school experience for 28 full-time students.

Arrangements have now been made with the chemicals division of the General Electric Company for a new station at their Waterford, New York and Selkirk, New York chemical plants. Together with Oak Ridge, these stations will enable us to provide practice school experience for approximately 40 full-time students per year. The new station will open in September 1977 and will contribute significantly to the Practice School program.

During his visit in the fall term, Professor J. T. G. Overbeek of the University of Utrecht and Visiting Professor of Chemical Engineering at M. I. T. gave a number of seminars and prepared the text for a new subject, 10.621 Electrochemistry, to be offered jointly with the Department of Chemistry next spring.

Professor Armstrong arranged a series of graduate school seminars. Those visiting M. I. T. in the series were Professors Jay Bailey of the University of Houston, John B. Butt of Northwestern University, Tomlinson Fort, Jr. of Carnegie-Mellon University, Arnold G. Frederickson of the University of Minnesota, D. M. Himmelblau of the University of Texas, Joseph L. Katz of Clarkson College of Technology who was a Visiting Professor during spring term, Robert P. Merrill of the University of California at Berkeley, Dale F. Rudd of the University of Wisconsin, R. A. Schmitz of the University of Illinois at Urbana-Champaign, and Roger I. Tanner of the University of Sidney, Australia. Professor Ronald A. Hites also presented a seminar in this series. Visitors in the seminar series from industry were Dr. Duane Marsh of the Union Carbide Corporation and Dr. Keith W. McHenry of Amoco Oil Company.

FACULTY

Dr. John P. Longwell joined the faculty as Professor of Chemical Engineering in March. He had previously been associated with the Exxon Research and Development Company and was a Visiting Professor in the Department. He was recently elected to the National Academy of Sciences.

Professors Lloyd A. Clomburg and Robert E. Cohen were promoted to Associate Professor. Professor Cohen also completed his second year as Esther and Harold E. Edgerton Assistant Professor.

Professor William M. Deen and Professor Frederick A. Putnam joined the faculty in September. In addition, Professor Michael P. Manning returned to Cambridge after serving for two years as Director of the Oak Ridge Station of the School of Chemical Engineering Practice. Professors Putnam and Manning were named duPont Assistant Professors for 1976-77. The Department has received a four-year, \$243,800 RIAS grant from the National Science Foundation (NSF) which is expected to assist greatly in the development of these and other young faculty.

Professor Karen C. Cohen was appointed a Visiting Associate Professor of Chemical Engineering and has a joint appointment to the staff of the Division for Study and Research in Education.

Professor John M. Beér served as a Committee member of the International Flame Research Committee and attended its London meeting in July 1976 and the Paris meeting in March 1977.

Professor Clark K. Colton continued to serve on the Scientific Advisory Board of the Artificial Kidney-Chronic Uremia Program of the National Institutes of Health and on the editorial boards of the Journal of Membrane Science and the Journal of Bioengineering. He gave invited

seminars at the Worcester Polytechnic Institute, The City College of New York, Columbia University, and the University of Wisconsin. In November he will receive the prestigious Allan P. Colburn Award from the American Institute of Chemical Engineers.

Professor Evans continued to serve as Trustee and Treasurer of the CACHE (Computer Aids for Chemical Engineering Education) Corporation whose headquarters are located at M. I. T. He also was an invited lecturer at Northwestern University.

Emeritus Professor Hoyt C. Hottel served as Honorary Chairman of the American Flame Committee and chaired the meeting of the Committee at M. I. T.

Professor Howard received the Richard H. Wilhelm Lectureship in Chemical Engineering awarded by Princeton University, where he presented lectures on Coal Pyrolysis and Hydro-pyrolysis and on Soot Formation in Flames.

Professor Edward W. Merrill was invited speaker at a Symposium on Vascular Grafts sponsored by and held at the National Heart, Lung, and Blood Institute in Washington, DC, and at a Symposium on Biomaterials sponsored by the Downstate Medical Center of New York and the New York Academy of Sciences.

Professor Robert C. Reid received the Warren K. Lewis Award given by the American Institute of Chemical Engineers (AIChE) for his outstanding contributions to education. He also received the 1977 American Society for Engineering Education Lectureship in Chemical Engineering. He served on review panels for the Engineering Chemistry and Energetics Division of NSF, the Applied Science Division of Brookhaven National Laboratory, the Department of Chemical Engineering at Princeton University, and the Physical Chemists Division of the National Bureau of Standards. He was appointed vice chairman of the awards committee and served on the publication committee of the American Institute of Chemical Engineers.

Professor Adel F. Sarofim gave invited lectures in Australia at the University of Newcastle, at the Commonwealth Scientific and Industrial Research Organization, and at Australian Consolidated Industries. He also gave invited lectures at Brigham Young University and the University of Utah and the invited plenary lecture at the Argonne National Laboratory Conference on High Temperature Sciences Related to Open-Cycle Coal-Fired MHD Systems. He was appointed to the editorial boards of Progress in Energy and Combustion Sciences and of Combustion Science and Technology.

Professor Charles N. Satterfield gave an invited summary lecture on catalytic denitrogenation reactions at the Murphree Awards Symposium at the Annual Meeting of the American Chemical Society in March. He also served as a member of the ad hoc panel on Direct Combustion of Coal of the Commission on Sociotechnical Systems, National Research Council, and was the 1977 recipient of the Outstanding Faculty Award in Chemical Engineering.

Professor Smith continued to serve on the editorial board of the AIChE Journal and as Associate Director of the Arteriosclerosis Center. He gave an invited lecture at the University of Rochester.

Professor J. Edward Vivian continued as Executive Officer for the Department and as Director of the School of Chemical Engineering Practice. He also is an advisor to the Institute of Technology-Postgraduate (ITP) Foundation in Madrid on their program for advanced education in chemical processing.

Professor Glenn C. Williams was a member of the Advisory Committee on Pollution Abatement and Energy Conservation, Department of the Army, and of the Coordinating Research Council

of the Aviation Fuel Safety Task Force. He also was chairman of the Sixteenth International Symposium on Combustion held at M.I.T. in August. He is a member of the Editorial Board for Combustion and Flame published by the Combustion Institute.

RESEARCH

The research volume of the Department was approximately \$1.6 million compared to \$1.37 million in 1975-76 and \$1.0 million in 1974-75. When interdisciplinary research activity for which Department faculty are responsible is included, the volume is approximately \$2.4 million compared to \$1.6 million in 1975-76. The Department's research extends over a wide range of activity with energy and fuel projects, reactor performance, polymer studies, and biochemical and biomedical research accounting for a major portion.

Professors Howard, Raymond F. Baddour, and Herman P. Meissner supervised a study of acetylene production from coal in a process involving plasma heating and calcium carbide production. Bench scale equipment was used in an exploratory study of the rate and extent of coal conversion.

Professors Colton and Smith, in collaboration with Professor R. S. Lees of the Department of Nutrition and Food Science and Professor M. Stemerman of Harvard Medical School and Beth Israel Hospital, have been carrying out research on the transport of low-density lipoproteins (LDL, the major cholesterol-carrying molecule) and other plasma proteins to the arterial wall under normal and abnormal conditions to determine the role of these transport processes for understanding the genesis of atherosclerosis.

In collaboration with Professors D. I. C. Wang of the Department of Nutrition and Food Science and G. M. Whitesides of the Department of Chemistry, Professor Colton continued research in the area of enzyme engineering with a view to the development of an enzymatic ATP regeneration system for use with a process for cell-free synthesis of the polypeptide antibiotic gramicidin S from amino acid raw material. Dr. Barry A. Solomon, a research associate in the Department, participated in this research.

Professor Robert E. Cohen is conducting research on properties of elastomers with particular attention to the effect of carbon black properties on the thermo-rheological properties of filled elastomers and on the effect of elastomer blends.

Professor Deen, in collaboration with Dr. Barry M. Brenner of Peter Bent Brigham Hospital and Harvard Medical School, conducted research involving the permeability properties of blood capillaries in the kidney to determine the implications of these for both normal and pathological kidney functions.

A team of investigators led by Professor Evans has made substantial progress toward developing an advanced computing system for process engineering. The software system, named ASPEN (Advanced System for Process Engineering), will play an important role in the 1980s in analysis of new fossil energy processes. For a system such as a coal gasification plant, it will perform the steady-state energy and material balances, size the equipment, and carry out an economic evaluation. Dr. Paul Gallier joined the project as project manager, on loan from Monsanto.

Project PROCEED (Program for Continuing Engineering Education), directed by Professor Evans and Professor Myron Tribus of the Center for Advanced Engineering Study, completed its second year. The goal of the project is to develop a new approach to continuing education

based upon self-study modules oriented toward problems encountered by practicing engineers. A new delivery system is being developed so that users can access the modules much as they would call upon a consultant to assist them in their work. Professor Karen Cohen joined the project this year as associate director. A consortium of other universities, industry and professional societies will be organized to assist in the work of the project.

Professors Evans and Wang continued their study of the dynamics of a mixed culture of yeast growing on a mixed substrate. A model based on previous experiments was compared with experimental parameters to confirm the validity of the model. These results appear to be the first set of systematic experimental observations of the dynamics of mixed cultures growing on mixed substrates. Present work is aimed at explaining the complex phenomena observed.

Professors Evans and Howard conducted a study to model the tube-wall methanation reactor in which a porous catalyst is placed in a thin coat on the inside wall of the tube. Heat from the highly exothermic reaction is removed through the wall. The model has been used to determine the maximum temperature in the catalyst, the optimal catalyst thickness, and the possibility of multiple steady-state profiles.

Professor Christos Georgakis is developing laboratory experiments to demonstrate simple concepts of dynamics and control and their interface with a real-time computer. Of particular interest is the evaluation of order of magnitude versions of control theories that are needed in the area of process control. He also has developed a pore plugging model for the absorption of SO_2 by dolomitic stones used in the fluid bed combustion reactor.

Professor Howard, in collaboration with Professors Hottel and Meissner, is conducting research on the pyrolysis and hydrogenation of coal in gasification processes and on coal conversion processes based primarily on pyrolysis. The research is intended to answer questions on how to increase non-catalytic methane yields in hydro-gasifiers, how to decrease char yield and/or sulfur and nitrogen content of the char, and how to control the distribution of pyrolysis and hydro-pyrolysis products. Models also are being developed for use in the initial design and in the interpretation of pilot plant results. Dr. William A. Peters is participating in this project.

Professors Howard and Hites are supervising a project dealing with the generation of polycyclic aromatic hydrocarbons and soot in both pre-mixed and diffusion flames. Emphasis is on the experimental determination of the identities, concentrations, and emission rates of these organic compounds and soot under a range of operating conditions of practical interest with a view to evaluating their environmental impact.

Professors Longwell and Howard are conducting research to assess the technical and economic feasibility of carbonizing coal in the presence of sulfur-accepting salts to produce clean gaseous and liquid fuels suitable for use with gas turbines for generating peak load electricity. The process is designed to produce a low-boiling, low-sulfur and low-nitrogen liquid fraction which can be stored for use as peaking fuel while the char and heavier liquids are circulated to a fluid bed combustion steam generator. Professor Longwell also has been involved in the modeling of fluid bed combustion, a study of the decomposition of organic sulfur compounds over hot calcium oxide, and the assessment of pollution from advanced energy systems such as the recovery of potassium sulfate in MHD systems.

Professor Manning has initiated research in the areas of heterogeneous catalysis and industrial waste water processing. The catalysis work is directed to the study of high temperature catalytic reactions under conditions where the metallic catalyst surface area increases dramatically due to surface metallurgical processes.

Professor Merrill, in collaboration with Dr. John G. Trump of the Department of Electrical Engineering and Computer Science, directed research on the destruction of trace toxic compounds in waste water by electron irradiation in an NSF sponsored pilot program at the Deer Island (Boston) Municipal Sewage Disposal Facility. It was demonstrated that polychlorinated biphenyls and the herbicide monuron could be destroyed by relatively low doses of irradiation. The mechanism seems to involve the hydroxyl radicals arising from the radiolysis of water and not the direct radiation. In a related study, Professor Merrill investigated the effects of radiation on the settling and filtration characteristics of pulp slurries.

Professor Merrill, in collaboration with Dr. Edwin W. Salzman of Harvard Medical School and Beth Israel Hospital and Professor David F. Waugh of the Department of Biology at M. I. T., conducted research to produce blood compatible biomaterials. New experimental forms of polyurethanes in which the soft-segment phase consists of different types of polyethers and of polymer surface to which heparin is covalently bonded by new techniques using carbodiimide are being evaluated. Dr. Robert Rosenberg of the Sidney Farber Cancer Center and Professor C. S. P. Sung of the Department of Materials Science and Engineering at M. I. T. are participating in this research.

In the Liquefied Natural Gas (LNG) Research Center, Professors Reid and Smith are conducting studies of the rate of boiling of both LNG and LPG (liquefied petroleum gas) on water. The emphasis in the LNG work is on the effect of composition of the LNG as small variations can significantly affect boiling rate. In the LPG studies, attempts are being made to understand why the boiling flux is so much larger than that for LNG. In a related study, the effect of spills of LNG on solid substrates such as insulating concretes, soil and sand were studied with a view to determining rates of boiling and to improving current understanding of the heat transfer mechanism involved. Studies also are continuing on light hydrocarbon vapor explosions on water to test the possibility of such events when the water temperature greatly exceeds the superheat limit temperature of the cryogen. While methane-rich LNG and pure ethane do not ordinarily explode on ambient water, by impacting such cryogens upon a water surface, an impressive vapor explosion can be produced. Studies on the production of LNG gels have been completed. Rheological properties of gels with water and methanol were measured and the structure determined. While gels of any consistency could be prepared, it does not appear to be an economically viable way to store and transport LNG although it does offer safety advantages.

Professors Smith and Reid also are investigating rollover in large LNG storage vessels. The phenomenon results from stratification due to variation in composition and density of the LNG added to the vessel if mixing is insufficient. Subsequent heat leak to the tank eventually leads to density equilibration and mixing, but this may be accompanied by such a rapid release of vapor as to pose a safety hazard. Likewise, it is well known that unless special precautions are taken, the flow of ordinary hydrocarbons may result in an electrostatic discharge, and studies are now under way to establish whether LNG requires similar precautions.

Professor Reid continued his studies on the high temperature heat capacities of liquid polar compounds, verifying the unusual behavior of such materials in the reduced temperature range around 0.8. Superheat limit temperatures also are being measured with a view to developing theoretical approaches to predicting such temperatures from kinetic theory and from classical thermodynamics.

In addition, Professor Reid is supervising a project to improve the catalyst for the carbon dioxide-hydrogen reaction to produce water and carbon. Electrolysis of the water product provides recycle hydrogen for the reactor and a regenerable source of oxygen for long-range space flights.

Professors Sarofim and Beér have been studying the mechanism by which nitric oxide is produced during the combustion of coal. Time-resolved measurements of the nitrogen release by the char and its conversion to nitric oxide have been obtained which should provide guidance in the development of control strategies to limit nitric oxide formation. In a related study they are investigating the kinetics of the NO reduction reaction with char with a view to developing a better understanding of the mechanism of nitrogen oxides emission from fluidized bed combustors. In another project they are studying the pyrolysis of coal experimentally at temperatures up to 2700°K in order to provide inputs for a model of an MHD combustor. In support of the national program they also have developed fluidized bed combustors.

Professors Sarofim and Howard have been studying the kinetics of char oxidation and the char-CO₂ reactions in a laminar flow furnace at temperatures up to 1822°K with a view to determining the contribution of pore diffusion to the total rate.

In parallel programs utilizing a pre-mix burner in the Department of Chemical Engineering and a smaller-scale oil-fired facility in the Department of Mechanical Engineering, Professors Sarofim and Longwell are investigating experimentally the feasibility of controlling the emission of nitrogen oxides from nitrogen rich fossil fuels by a preheat process under fuel rich conditions.

Professors Sarofim and Smith are investigating the kinetics of nucleation of ice particles as part of a broader program on the freeze process for desalination, focusing current research on the use of a batch crystallizer to determine the kinetics of nucleation. Population balance analysis has been used to relate the temperature increase of the crystallizer to nucleation parameters, and the predictions of the theory are being tested in a complementary experimental program.

Professors Sarofim, Williams, and Clomburg are investigating the formation of nitrogen oxide in a laminar diffusion flame in complementary theoretical and experimental programs, and previous results on the flow field obtained from a numerical simulation now have been verified experimentally. Evidently the NO_x is produced on the fuel-lean side of the flame front, part of which diffuses into the flame where it is destroyed by reaction with hydrocarbon radicals forming HCN as an intermediate between NO_x and nitrogen.

Professors Smith and Colton are studying the factors which influence the ultrafiltration of macromolecular solutions by measuring concentration profiles of albumin in a batch filtration cell with shadowgraph techniques, and are correlating the results with the measured ultrafiltrate flux and a theoretical model. An interferometric method for diffusivity determination has been developed as part of this effort. This research has application to physiological processes as well as to commercial membrane separation of proteins and synthetic macromolecules.

Professors Satterfield and Colton continued their research on a variety of effects that occur when dealing with solutes inside pores of dimensions comparable to that of the solute. Equilibrium partitioning is markedly affected by bulk concentration, and increases much more than can be accounted for by any present theory.

Professor Satterfield also continued his research on the trickle bed reactor with particular attention to the rate of mass transfer from the bed to the liquid under various gas and liquid flow rates. Mathematical correlations were developed for the various regimes.

Professors Satterfield and Michael Modell supervised a project to study the hydrodenitrogenation (HDN) of quinoline on a sulfided commercial NiMo/Al₂O₃ catalyst in a continuous flow

microreactor at pressures up to 1,000 pounds per square inch and temperatures up to 420° C as part of a program to determine mechanisms for converting N-containing compounds in fuels to hydrocarbons.

KENNETH A. SMITH

Department of Civil Engineering

The past year has been one of considerable accomplishment and important development for the Department in spite of budgetary constraints which severely limit our ability to take new initiatives. Undergraduate enrollment continued to increase to its highest level in more than two decades; the undergraduate program was considerably strengthened by the reintroduction of a fourth-year design subject which integrates the students' previous work; graduate enrollment was intentionally reduced somewhat to a more manageable level; the research program continued its strength in content, size, and diversity; important new research initiatives were taken; an extensive search was conducted to identify candidates for up to nine faculty positions which have or will soon become available through termination; and the faculty continued their record of personal achievements through publications, awards, and public service.

A major concern of the department in recent years, and particularly during the past year, has been the impact of budgetary constraints on our ability to offer an educational program of high quality, and the extent to which these constraints create a feeling of dependence on our sponsored research program. In terms of constant dollars, our academic budget has dropped by more than 10 percent since 1968. During that same time period, our faculty size increased by 15 percent, undergraduate enrollment increased by 159 percent, and graduate enrollment increased by 22 percent. In order to accommodate these changes, it became necessary during the past year to impose rather major budgetary constraints including a reduction in the number of teaching assistants from the normal level of 20 to a current level of 11, elimination of academic summer support, a severe cutback in curriculum development and unsponsored research support, and a reduction in the number of support personnel. During this same period research support has continued to grow, and faculty support on research has remained at about the 35 percent level. However, the nature of the support has changed toward mission oriented research and the generation of immediately usable results, and away from long-term, fundamental studies. Thus, there is a greater pressure on the faculty; and we have responded by depending more heavily on full-time, professional research staff members and less on graduate student assistants. The net effect of these changes has been to increase our dependence on research support and to reduce opportunities for taking educational initiatives.

Undergraduate Program

Interest in our undergraduate program continued at a high level with the total undergraduate population rising by 28 from the preceding year to a total of 176 students. This is not only our highest enrollment in over 20 years, but also represents the largest enrollment increase in that period.

As this enrollment approaches that of our graduate student body, we have begun to consider the question of an optimum size for the undergraduate class. There is general agreement

that the present size is nearly ideal in many respects and that further large increases will necessitate the generation of substantial new resources. However, there is reason to believe that our undergraduate enrollment has, in fact, nearly reached its peak and that we may anticipate a leveling, or even a slight decline over the next few years.

A major change in the undergraduate curriculum was effected by the re-establishment of a fourth-year design requirement. The requirement is met by taking one of three so-called "capping" subjects which were offered by each of the Department's three major divisions for the first time during the past year. These subjects utilize realistic design projects to motivate an integration and application of the students' prior educational experiences. In these projects students are required to participate in the identification of objectives, generation and evaluation of alternative solutions, design of specific alternatives, and development of implementation strategies. The projects for the past year were:

Constructed Facilities Division: "Design and Construction of Offshore Structures"

Transportation Systems Division: "Development of a Transportation Plan for the Boston Area Northwest Sector"

Water Resources and Environmental Engineering Division: "Design of Projects for Integrated Development of the Vardar-Axios River Basin "

The three capping subjects were considered to be highly successful by the faculty and participating students, and represent an important addition to the educational experience of our students.

The Transportation Systems Division took the lead in working toward a departmental cooperative program by offering an undergraduate seminar, 1.21 Cooperative Program in Transportation. In this seminar, which was directed by Professor Steven R. Lerman, students worked in public and private transportation agencies in the local area for approximately 12 hours per week and met weekly with Professor Lerman to discuss and evaluate their experiences.

A renewed emphasis was placed on laboratory experiences as an integral part of the undergraduate curriculum. Professor James M. Becker was extremely successful in generating interest in his subject, 1.105 Structural Engineering Laboratory, and has now obtained an agreement for joint participation by the Department of Architecture. Professor Becker also has begun the design and acquisition of equipment for a new experimental test facility for this subject. The two subjects, 1.106/1.107 Water Resources and Water Quality Laboratory Projects, which are taught by Professors Bryan Pearce, Francois M. M. Morel, and Sallie W. Chisholm, increased their emphasis on fieldwork, an activity which we hope to expand even more in the future.

The rest of our undergraduate curriculum remained essentially unchanged. However, the Undergraduate Committee of the Department, under the effective leadership of Professor Fred Moavenzadeh, conducted an extensive review of two of our core subjects, 1.13 Behavior of Physical Systems and 1.14 Resource Allocation and Project Evaluation. Recommendations for substantial changes in both subjects have been made, and plans for their implementation during the next year are under way.

The Undergraduate Committee also defined major issues of concern for the future development of our undergraduate program. These include a desire to increase the participation of undergraduates in our research programs, to integrate the computer more fully into our educational processes, to place more emphasis on the creative and innovative processes, and to integrate the social sciences more fully and naturally into the curriculum.

Graduate Program

Although applications to our graduate program have continued at a high level in terms of quality and numbers, we elected in the preceding year to reduce the graduate enrollment somewhat from its peak level of 225 students in the 1975-76 academic year. As a result, enrollment was reduced to a total of 202 regular graduate students with a major portion of the reduction occurring in the Constructed Facilities Division. The reduction was considered necessary in order to maintain the quality of our graduate program in a time of increasing undergraduate enrollment and the previously mentioned reduction in teaching assistants and other support personnel. It is anticipated that graduate enrollment will increase slowly in the next few years.

Graduate student support for this past year and three previous years has come from the following sources:

	<u>1973-74</u>	<u>1974-75</u>	<u>1975-76</u>	<u>1976-77</u>
Fellowships and Traineeships	43	60	76	60
Research Assistantships	98	87	92	91
Teaching Assistantships	20	19	19	13
Other (including self-support)	<u>43</u>	<u>45</u>	<u>38</u>	<u>38</u>
TOTAL	204	211	225	202

It is interesting to note that the number of research assistantships has remained relatively constant over this period as has the total size of our faculty which, to a large extent, determines the number of research assistantships. Of great concern, however, is the reduction in teaching assistantships which was required by the constrained academic support. Not only does this reduction in support weaken our ability to attract graduate students, it also represents a constraint on our ability to provide the best possible education. Also of concern is the relatively small number of fellowships and traineeships. Of the 60 listed in the table, 21 are provided by foreign sources for foreign students and 6 are government support for members of the armed forces on active duty. Thus, only 33, or 16 percent of the graduate student body, are supported on fellowships and traineeships over which we have direct or indirect control. There is an increasing concern that this situation has a serious impact on our ability to attract the very best US graduate students.

The total number of graduate applications increased by almost 17 percent to a total of 391. This brought the number of applications back to the high level of the preceding year and is attributed, in part, to the increased undergraduate enrollments nationwide in civil engineering in recent years. A total of 180 applicants were offered admission and 98, or 54 percent, of these have accepted admission. Those accepted include 8 minority students, 8 women, and 32 foreign students. The latter figure is 33 percent of the total acceptances, a considerable reduction from the 44 percent figure of the preceding year.

We have conducted a survey of those graduate students who were admitted but chose not to come to M. I. T. Although only 19 replies have been received to date, almost half (nine) cite the presence of a better financial aid offer from another school as the principal reason for their decision. Other major reasons included M. I. T. 's location, the perceived content of our programs, and the length of time required to obtain a Master of Science degree.

Thanks to the leadership of our Graduate Admissions Officer, Professor Richard L. de Neufville, and the staff of our Academic Programs Office, the admissions process has been placed on an extremely responsive, efficient, and personalized basis.

During the past year the Department Committee on Graduate Students, under the chairmanship of Professor Jose M. Roesset, has considered a variety of topics, the most important of these being a clarification of departmental policy relative to the allowable academic load that may be carried by new and continuing research assistants. Although no change in official policy was effected, the clarification of how that policy should be implemented and applied to special cases has been helpful.

A major revision of the doctoral program in Transportation and a new program in Construction Engineering and Management were approved by the Committee. The latter, which combines basic systems methodology, planning and modeling of construction processes, and design/analysis of physical systems, represents an important new direction for the Department.

RESEARCH

The total volume of research administered by the Department during the past year remained at about the level of \$2.5 million. However, because a large number of projects conducted by our faculty are administered through special interdepartmental entities such as the Energy Laboratory and the Center for Transportation Studies, our total research volume is expected to be close to \$5 million.

Our research support is derived from a large and diverse set of sponsors; thus the research program is not inordinately dependent on any single source. The largest sources of Federal support include several agencies of the Department of Transportation, the National Science Foundation, and the US Agency for International Development. However, support is also received from many other agencies including the Energy Research and Development Administration, the Office of Water Resources Research, the National Oceanographic and Atmospheric Administration, the Federal Railroad Administration, the Federal Energy Administration, and several others. A major amount of industrial support also has been received, this coming primarily from electrical utilities in support of various waste heat management studies at the Ralph M. Parsons Laboratory.

The research program continues to be an integral part of our educational program; it provides financial support for nearly one-half of our graduate students, serves as the basis for a majority of our graduate theses, and acts as an important catalyst for change in the curriculum. A continuing concern is the extent to which we are dependent on research support and the attendant absence of unrestricted research funds with which to initiate new areas of inquiry.

A complete description of current research projects is provided in the publication, Background Information on the Department of Civil Engineering, which is available from the Department of Civil Engineering Headquarters.

FACULTY

During the past year resignations were received from the following faculty members: Professor Michael S. Baram entered full-time law practice in Boston. Professor Carlos F.

Daganzo joined the faculty at the University of California at Berkeley. Professor Charles H. Dowding joined the faculty at Northwestern University. Professor Roberto Lenton will join the Ford Foundation in their New Delhi, India office. Professor David C. Major has accepted an appointment as Visiting Professor in the School of Geography at Clark University. Professor Wayne M. Pecknold joined the firm Cambridge Systematics, Inc. in Cambridge, Massachusetts.

Professor Stanley A. West will become a Research Associate in the Department and will be on leave at the Waterways Experiment Station of the Army Corps of Engineers, in Vicksburg, Mississippi. Professor Stamatia Frondistou-Yannas will remain in the Department as a Research Associate.

An intensive search for new faculty members has resulted in the following new appointments: Dr. David Ashley, a graduate of our Department and recent recipient of the Ph.D. from Stanford University, will join the Constructed Facilities Division as an Assistant Professor. Dr. Terry L. Friesz recently received his Ph.D. from Johns Hopkins University and will join the Transportation Systems Division. Professor D. Peter Loucks of Cornell University will be a Visiting Professor in the Water Resources and Environmental Engineering Division. Professor Vincent Roggeveen of Stanford University will be a Visiting Professor in the Transportation Systems Division for fall term.

During the past year four members of the faculty were on sabbatical leave. Professors David H. Marks and Daniel Roos remained in the local area to write and conduct personal research. Professor William A. Little spent spring term with the Fluor Corporation in San Diego, and Professor Robert V. Whitman spent the year at Cambridge University in England. In addition, Professors Charles L. Miller and William W. Seifert both continued their leaves of absence for a second year.

Three faculty members received promotions. Professor Joseph M. Sussman was promoted to the rank of full professor, while Professors Mohsen M. Baligh and Moshe Ben-Akiva were promoted to the rank of associate professor.

Faculty of the Department provided leadership for important interdisciplinary programs. These included Professor Paul O. Roberts, Director of the Center for Transportation Studies; Professor Jerome J. Connor, Director of Research for the M.I.T. Sea Grant Program; Professor Moavenzadeh, Director of the Technology Adaptation Program; Professor Richard L. de Neufville, Director of the Technology and Policy Program; and Professor Peter S. Eagleson, Director of the Environmental Engineer Degree Program.

Two faculty members were honored by the American Society of Civil Engineers. Professor C. Allin Cornell was selected along with Dr. Hans A. Merz to receive the 1977 Moisseiff Award for their paper, "Seismic Risk Analysis of Boston." Professor David H. Marks was selected as recipient of a 1977 Walter L. Huber Civil Engineering Research Prize. The Boston Society of Civil Engineers Section of the American Society of Civil Engineers also honored two faculty: Professor Whitman received the Ralph W. Horne Prize for outstanding, unpaid public service, and Professor Charles C. Ladd was elected President of the Section at its annual meeting in April.

Professor Ole S. Madsen received the Department's Effective Teaching Award for the second time. Professor Madsen also was named as the third Henry L. Doherty Professor in Ocean Utilization.

Professor Nigel H. M. Wilson was awarded a funded Visiting Professorship in Planning by Stanford University, and also received a fellowship for travel by the Marion and Jasper Whiting Foundation.

Department of Electrical Engineering and Computer Science

Professor Lerman was appointed as the third holder of the Gilbert W. Winslow Career Development Chair in Civil Engineering.

Publications

During the past year the following books were published or accepted for publication: Climate, Soil and the Water Balance by Professor Eagleson, The Mexican Aztec Society by Professor Stanley A. West, Airport Systems Planning by Professor de Neufville, and Multiobjective Water Resource Planning by Professor David C. Major.

FRANK E. PERKINS

Department of Electrical Engineering and Computer Science

Student interest in both electrical engineering and computer science has continued to grow at M.I.T. Preliminary evidence suggests that next year, 31 percent of the designated sophomores will have selected electrical engineering or computer science, compared with 27 percent this year, and 25 percent the year before.

While this increase is gratifying, we expect increased difficulties in carrying out the teaching mission within our allocated budget. In recent years, the Department has been forced to deplete some of its accumulated reserves. This year, these reserves "hit bottom" and more drastic action was necessary. The number of teaching assistants planned for next year is down by a third, and this means that for the first time since the early 1960s, we will be unable to offer the greatly appreciated and effective tutorials in most of our undergraduate core subjects. Many faculty feel that this will mean a lowering of quality of instruction, although we are hopeful that this lowering will prove minimal.

This year a committee under the direction of Associate Department Head Paul Penfield has been examining our common core, which is a set of four subjects common to both the computer science and electrical engineering undergraduate curricula. Relatively large changes are expected in three of these four subjects, with a renewed emphasis on applications and hands-on experience, and a decreased emphasis on elegance and generality for their own sakes. Development of the common core will take place over the next few years.

Undergraduate Program

Past projections of increased undergraduate enrollment in Electrical Engineering and Computer Science have proven to be very inaccurate since the year-to-year increase was roughly twice our estimate, the current figure being about 850 students as against an estimate of 800. Present (optimistic) projections indicate that enrollment in the Department should increase to about 900 in the 1977-78 academic year. Since resources available to the Department have not increased commensurate with the student load, we have been forced to re-examine modes of teaching with hopes for increasing the efficiency of delivery of our services without a significant sacrifice in the quality of our teaching. The major change which has been put into effect has been to eliminate the tutorial mode in most of our introductory core subjects.

The Common Core Curriculum Committee has essentially completed its examination of the undergraduate core and will be reporting its conclusions and recommendations to the Department in the fall. A much closer linking of the Electrical Engineering and Computer Science programs is anticipated.

Beginning in fall, 1977, the Concourse program for first-year students will be officially administered by the Department under the leadership of Professors David Adler and Jerome Y. Lettvin. This move reflects the decision of the Committee on Educational Policy to make Concourse a permanent program in the freshman year. It was placed under the Department's aegis because of our primary interest in leadership and excellence in undergraduate education.

For leadership and service to the Department and his fellow students, the Scott Paper Company Leadership Award was won by Mark J. Smith of Jamaica, New York, Chairman of the Department's Student-Faculty Committee. The Ernst A. Guillemin Prize for the outstanding undergraduate thesis in Electrical Engineering was awarded to Solomon R. Eisenberg of Chicago, Illinois. The Computer Systems Prize for the outstanding undergraduate thesis in Computer Science was awarded to Brett L. Bachman of Downers Grove, Illinois. John C. Doyle of St. Petersburg, Florida, won the Hickernell Award from the Power Engineering Society of the Institute of Electrical and Electronics Engineers (I. E. E. E.) for the best paper presented at the Winter Power Meeting, January 1977. His work was supervised by Professor Nils R. Sandell.

Graduate Program

The number of both graduates and undergraduates in the Department has been increasing in recent years. Since the number of faculty has remained relatively constant because of budget constraints, it has been necessary to reduce the number of graduate students, even though the number of outstanding applicants continues to be large. At the same time, budget limitations will lead to a reduction in the number of teaching assistants in the Department, probably to a level of 75 for 1977-78.

As a consequence of this reduction in teaching staff, it has been necessary to reduce somewhat the number of subject offerings at both the graduate and undergraduate level. Since continued operation at this level of staffing might seriously affect the quality of our educational program, the Department is actively seeking increased support for future years.

Awards for outstanding teaching by graduate students were bestowed upon Robert R. Buckley, Mohammed Dadashzadeh, Robert M. Halstead (who all received the Supervised Investors Services awards) and to Marvin S. Keshner who received the Carlton E. Tucker award. Michael R. Portnoff, a Ph.D. candidate, was named recipient of the I. E. E. E. Browder J. Thompson Memorial Prize for a research paper in the field of generation and utilization of electric power. Professor James H. McClellan was one of the six M. I. T. faculty members to whom the Graduate Student Council presented teaching awards for outstanding teaching on the graduate level.

Cooperative Program (VI-A)

During this year, the popularity of the VI-A Program continued to grow. The 165 students who applied for admission in spring, 1977 exceeded last year's all-time high by 14.6 percent. They represented 52.7 percent of sophomores in the Department of Electrical Engineering and Computer Science, a 4.7 percent increase over last year. Of the 165, 102 ultimately appeared on company preference lists and 73, or 44.2 percent of those applying, were finally admitted as the new VI-A Class of 1977.

Course VI-A enrollment in all classes reached 174 in fall, 1976, or 12.5 percent of the Department's total undergraduate and graduate enrollment. This compares to 10.2 percent the year before.

During the academic year 1976-77, 34 VI-A students were awarded the combined S.B./S.M. degrees under the five-year plan, with three of these also earning the E.E. degree. Five others completed the S.M. degree after having received the S.B. degree earlier. Eight stopped at the S.B. degree, only, and will not pursue further studies at M.I.T.

The Department was pleased that arrangements were completed with the Xerox Corporation in time to add their Palo Alto Research Center (PARC) to the Program in spring, 1977. Their representative selected two students to start their first year on VI-A. In three years they hope to have a minimum of six students working at PARC. It is anticipated that other Xerox facilities will be added as the company gains experience with the Program.

RESEARCH

Most research is performed in departmental or interdepartmental laboratories. A few results are noted briefly here. More complete information appears in portions of this report dealing with the following laboratories: the Electrical Power Systems Engineering Laboratory (E.P.S.E.L.), the Research Laboratory of Electronics (R.L.E.), the Laboratory for Computer Science (L.C.S.), the Artificial Intelligence Laboratory, the Energy Laboratory, the Electronics Systems Laboratory, the Operations Research Center, and the Center for Materials Science and Engineering (C.M.S.E.).

Amorphous Semiconductor Theory

Professor Adler, in collaboration with Professor Marc A. Kastner of the Department of Physics and Professor H. Fritzsche of the University of Chicago, has developed a new model for the electronic structure of amorphous semiconductors. This model, based on the chemical nature of the constituent atoms of the solid, accounts for many of the unique properties of chalcogenide glasses in a natural way. Using the results of the model, Professor Adler has developed a quantitative explanation of the threshold switching phenomena which characterize these glasses. This analysis suggests methods for improving the performance of such switches.

Control of Economic Systems

Professors Michael Athans, Edwin Kuh (Department of Economics), and Robert S. Pindyck (Sloan School of Management) together with a team of graduate students have been investigating fundamental problems of applying modern control and estimation theory to complex models of the US economy. The main objective of this study is to understand how feedback control can be used for short-term stabilization strategies using different economic policy variables and different objective functions.

Manufacturing Systems

Professors Athans, Alvin W. Drake, Leonard A. Gould, and Nathan H. Cook (Mechanical Engineering), Dr. Stanley B. Gershwin, and John E. Ward have initiated a study that is directed toward understanding the complex issues associated with problems of batch manu-

facturing, in both the metal cutting and electronic manufacturing industries. The objective of this study is to understand how to increase the productivity of manufacturing through automation and the use of sophisticated scheduling algorithms.

Electromechanics of Charged Membranes and Connective Tissue

Professor Alan J. Grodzinsky and his students have developed theoretical and experimental techniques enabling the characterization of electrical-mechanical-chemical energy conversion processes in certain physiological and artificial membranes and tissues. These techniques have been incorporated into the design of prototype transductive coupling devices, and the application to biologically compatible active, implantable assist devices. In addition, a collaborative research program has begun with members of the Orthopaedic Research Laboratory at Children's Hospital Medical Center, concerning the molecular origin of certain electromechanical properties of connective tissues. Experiments involving cartilage, tendon, and other collagenous tissues are under way; the goal is to relate the measurable electromechanical properties to tissue structure and function.

Noise in Nonlinear Devices

Professor Madhu S. Gupta has approached the long-standing problem of calculating noise in nonlinear devices by selecting a class of devices under small, steady-state excitation. He has arrived at a theoretical result which has been tested on, and found applicable to, several semiconductor devices. The result provides a unified approach for calculation of noise in nonlinear devices, and an examination of the conditions under which it is applicable can lead to a better understanding of the nature of fluctuations and nonlinearity in electronic devices.

Programming Methodology Group

Professor Barbara H. Liskov and her students have been studying the construction and verification of well-structured programs. The approach taken is based on a programming methodology in which the recognition and use of abstractions plays a major role in the process of program construction. Several kinds of abstractions that are useful in this process have been identified. Two major research directions are being pursued: the design of the programming language, CLU, which supports programming with abstractions by means of novel linguistic mechanisms, and the development of specification and verification techniques for programs using abstractions.

Digital Signal Processing

The efficient calculation of discrete Fourier transforms using the recent algorithm due to Winograd is the subject of research being carried out by Professor McClellan and several graduate students. Issues pertaining to special purpose computer implementations and finite wordlength effects are being studied in order to compare this new algorithm with the well-known fast Fourier transform.

Cryptographic Algorithm for Communications

Professor Ronald L. Rivest, in conjunction with Drs. Adi Shamir and Leonard M. Adelman (of the Department of Mathematics), has developed a novel cryptographic scheme based on the difficulty of factoring large numbers. In addition to ensuring privacy of communications,

this scheme enables users to produce a recognizable, but unforgeable, message-dependent digital "signature" for a message. The scheme therefore has widespread potential applications in the area of "electronic mail" and "electronic funds transfer" systems.

Charge-Flow Transistor

A new solid-state device, the Charge-Flow Transistor, has been developed by Professor Stephen D. Senturia and his students. The device is designed to permit monitoring of the sheet resistance of gas-sensitive polymer films for applications such as fire detection and humidity measurement. The Charge-Flow transistor is based on MOS technology (the same principle used in the calculator chip), and can be fabricated as part of a chip that provides the sensing device and all associated electronic circuitry within a single integrated circuit. The device also has important applications as a research tool for the study of electrical conduction processes in thin films. Development of this device was supported by the National Aeronautics and Space Administration.

Problem-Solving Strategy

At the Artificial Intelligence Laboratory, Professor Gerald J. Sussman and his group have been studying the problems of intelligent failure recovery in problem-solving programs. They are building a problem solver for electrical design which will learn as much as it can from its mistakes. They cast the engineering design process in terms of "Problem Solving by Debugging Almost-Right Plans," a paradigm for automatic problem solving based on the belief that creation and removal of "bugs" is an unavoidable part of the process of solving a complex problem. The process of localization and removal of bugs called for by the PSBDARP theory requires an approach to engineering analysis in which every result has a justification which describes the exact set of assumptions it depends upon.

High Voltage Research Laboratory

Activities at the High Voltage Research Laboratory (HVRL), under the direction of Professor John G. Trump, bring together disciplines from the biological and physical sciences. In one project, high energy electrons from a powerful accelerator convert an environmentally hazardous waste material into a safe plant nutrient and soil conditioner. The material, wastewater sludge collected by municipalities, has become a national and global problem. With the Departments of Chemical Engineering and Nutrition and Food Science, radiation disinfection studies are in progress at a large-scale sludge disinfection facility erected with National Science Foundation support at Boston's Metropolitan District Commission Wastewater Treatment Plant on Deer Island. Bacterial and viral disinfection, toxic chemical breakup, and economics and modes of utilization are evaluated.

Other HVRL programs include cooperation with the physicians of the Lahey Clinic in the treatment of malignant disease with megavolt X-ray and electron radiation, the development of a compact three-megavolt electron source for the treatment of malignancies of the skin, and investigation of vacuum and compressed gases as high voltage dielectrics. Compressed gases promise more efficient, higher capacity electric power transmission systems. In recent studies the Laboratory's unique five million volt test facility demonstrated the capacity of gases to insulate the highest voltages contemplated by the electric power industry for underground power transmission.

Control of Urban Transportation Systems

Professors Athans and Alan S. Willsky, and Drs. Stanley B. Gershwin and Paul K. Houpt, together with a team of graduate students, have been investigating the feasibility of using advanced modern estimation and control methods for the real-time control of traffic networks. The research includes incident detection, estimation of loss in freeway capacity following an incident, real-time control of traffic signals, ramp metering, and the effects of modal split.

FACULTY

Faculty promotions include Joel Moses to Professor; and Ira P. Goldstein, Alan J. Grodzinsky, Michael Hammer, James L. Kirtley, Jr., Ronald Rivest, Nils R. Sandell, Jr., and Gerald Sussman to Associate Professor.

Also, Associate Professor Roger G. Mark became one of the first two holders of the Matsushita Professorship of Electrical Engineering and Medicine, and Professor Kenneth N. Stevens has been appointed to the Department's Charles Joseph LeBel Audio Engineering Professorship.

Professor Cyril Leung received the Ph. D. from Stanford University where he was the 1975 King George VI memorial fellow, and joined the M.I.T. faculty in September 1976 as Assistant Professor of Electrical Engineering.

Professor Mildred S. Dresselhaus has been named director of M.I.T.'s Center for Materials Science and Engineering, succeeding Dr. Nicholas J. Grant, ABEX Professor of Advanced Materials, who headed the Center since 1968. Professor Jonathan Allen has been appointed associate director of M.I.T.'s oldest interdepartmental laboratory, the Research Laboratory of Electronics.

The Plasma Fusion Center was established under Dr. A. G. Hill (consultant to the President and the Chancellor) and includes several of the Department's faculty. Among them are: Professors Abraham Bers, Ronald R. Parker, and Louis D. Smullin; and on the Academic Committee of the Center is Professor Wilbur B. Davenport, Jr., Department Head.

Professors Emeriti John G. Trump and Arthur R. vonHippel have been elected to membership in the National Academy of Engineering. Major honors from I.E.E.E. were bestowed on President Jerome B. Wiesner, the 1977 recipient of the I.E.E.E. Founder's Medal for major contributions in leadership, planning and administration of affairs of great value to the electrical and electronics engineering profession; and to Professor Robert M. Fano the I.E.E.E.'s Education Medal. Professors James R. Melcher, William F. Schreiber, Fred C. Schweppe, Gerald L. Wilson, and Dr. Alexander Kusko (Lecturer) were elected Fellows of the I.E.E.E. Professor Davenport was elected Fellow of the American Academy of Arts and Sciences, and Professor Athans was elected a Fellow of the American Association for the Advancement of Science.

The Department was pleased to welcome the following Visiting Faculty during the academic year: Professor Louis-Francois Pau, of the Ecole Nationale Supérieure des Telecommunications in Paris, worked with the Cognitive Information Processing Group in pattern recognition with interest to its application to industrial processes; and Professor Markus Zahn, Associate Professor in the Department of Electrical Engineering at the University of Florida, Gainesville, visited with Professor Melcher and worked on air pollution control.

Department of Materials Science and Engineering

The Department also had a Vinton Hayes Fellow, Dr. Earl R. Barnes on leave from IBM Watson Research Center, who worked here with Professor Athans on computational problems arising in data communication networks and transportation systems.

Department faculty who were away this year include Professors Murray Eden and William T. Peake. Professor Eden is on leave of absence and has been named chief of the Biomedical Engineering and Instrumentation Branch of the National Institutes of Health's Division of Research Services in Washington, DC. Professor Peake was on sabbatical from academic duties during the past year, during which he pursued his research on mechanical properties of the middle and inner ear, at the Eaton-Peabody Laboratory, Massachusetts Eye and Ear Infirmary, Boston.

Professor David D. Redell has left the Department faculty to do research at the Xerox Corporation, Palo Alto Research Center, and Professor Adrian Segall resigned his faculty position to return to Israel and join the Department of Electrical Engineering at the Technion, Israel Institute of Technology.

Professor J. Francis Reintjes retired as Professor of Electrical Engineering but is continuing his research and his extremely active role as the Department's admission and registration officer for special students.

WILBUR B. DAVENPORT, JR.

Department of Materials Science and Engineering

Undergraduate Program

Ever since we reorganized our undergraduate program about five years ago we have been working hard to increase the number of undergraduates in Materials Science and Engineering. Over the last few years the number increased slowly. With our goal of 35 students in each of the junior and senior years, we would be teaching a minimum of 30 students in each subject. This is about the limit we could properly teach with our existing faculty and resources. If the numbers in each subject increase substantially more than 35 we will have to duplicate sections and find some additional teaching effort. We have not yet reached the goal of 35 students in each year, but we appear to be approaching it rapidly. In 1976-77, 26 sophomores registered in Course III and we expect this number to increase by the time they become juniors. There were 16 students in the junior and 11 students in the senior year. Thus, we had a total of 54 undergraduates in the Department, the largest number since the early 1960s. In 1972 we had only eight sophomores and a total of 34 undergraduates registered in Course III. Furthermore, in May 1977, 31 freshmen indicated that they are likely to register in Course III next year. Thus, we anticipate a total undergraduate population of 85 or more in 1977-78.

Clearly, many of the new students are attracted by our cooperative program, Course III-B. This first began two years ago, in a modest fashion. During the last academic year we had many more applications than we could handle. The major problem has been, and continues to be, to find suitable jobs in industry. Professor Thomas B. King and the Course III-B

Committee have worked very hard to find places for as many students as possible in industrial situations in which they can be properly supervised on appropriate projects. They have found positions for 20 students at the present time. If we could find suitable industrial locations, we could double this number. Naturally, this is a matter on which we are continuing to work. The establishment of a School-wide cooperative program should help us considerably in the development of Course III-B.

Graduate Program

The total number of graduate students in the Department of Materials Science and Engineering at the end of 1976-77 was 155. The number of graduate students whom we can admit is limited by the research funds we have available to support them and, of course, by the number of faculty available to supervise their thesis work. It is now evident that with our present faculty, resources, and space, the maximum number of graduate students we can support is close to 160. The maximum number ever registered in the Department at one time was 161 in 1967. Sixty-four percent of our graduate students (99 students) are employed as research assistants on research projects. In the School of Engineering only 44 percent of the graduate students are so employed. The number of teaching assistants in our graduate population is proportionately smaller than in the School of Engineering. The Department offers financial support to graduate students from foreign countries only in exceptional circumstances and when requested directly by a member of the faculty. Consequently, the increase in the total number of graduate students in the Department over the last three years has occurred at the same time as the proportion of foreign students has decreased. Close to 75 percent of our graduate students are citizens of the United States. Those foreign students admitted in 1976-77, most of them with their own support, came from more than a dozen different countries.

In recent years, our programs have attracted many women and minorities. At the present time, 20 percent of our graduate population are women -- a much higher fraction than in the School of Engineering as a whole. It is of interest that we also have a large proportion (22 percent) of women in our undergraduate programs. The proportion of our graduate students from minority groups also is increasing; it reached seven percent last year.

RESEARCH

The rapid expansion of our graduate population which has occurred in the last two years was possible only because of the dramatic increase in research funds, which was a direct result of the increase in the national research effort on materials for energy applications. At the end of 1976 the faculty of the Department were in receipt of research grants and contracts to a total value of \$12,770,739. The annual expenditure on research was \$4.3 million in 1976 and is estimated to be in excess of \$4.5 million in 1977. The pressure which this puts on the individual faculty member is very great. On the average, each member of the Department of Materials Science and Engineering spends \$140,000 per annum on research and provides nearly half of their annual salary from these funds. The time and effort absorbed by writing proposals, attending workshops, review meetings, and sponsors' visits, and by the fiscal management of many complicated budgets is much greater than when operating in the individual grant mode.

There has been a considerable change in the type of research we do. In the mid-1950s the work was largely applied science and was undertaken mainly by individual professors with their students and a few post-doctoral assistants. Nowadays, to an increasing extent, our

research is carried out by an interdisciplinary team of professors and professional scientists and engineers organized to tackle a specific major problem. In many cases, the collective effort involves groups of engineers from industry, government organizations, and private research groups. One example of research of this kind, currently under way, is the development of high-temperature, electrically conducting ceramic electrodes for coal gasification by MHD. On this project, which is organized through the Energy Laboratory at M. I. T., a group of ceramists including Professors H. Kent Bowen, Rowland M. Cannon, Robert L. Coble, and Bernhardt J. Wuensch is doing basic research on transport properties in ceramics as well as more applied measurements and testing, all contributing to the work of the design teams. Last year we built and equipped a new laboratory in the basement of Building 12 for work on the processing of ceramics. This rapidly expanding and important field of materials activity is closely linked to the need for improvements in ceramics for gas turbines, high temperature erosion resistant electrodes, laser windows, and many other advanced engineering applications.

Another example is the work of Professors August Ferdinand Witt and Harry C. Gatos on the growth of crystals of electronic materials. The part of this work which has received most attention was carried out on Skylab and Apollo space missions, but the program is larger than that and is closely linked with the efforts of electronic industries to develop highly perfect crystals of gallium arsenide and silicon. A third example is Professor Merton C. Flemings' development of rheocasting and the related processes of rheoforging and rheoforining. In this case, the research spans the spectrum from basic laboratory investigations of fluidity of semi-solid melts to the actual manufacture of components in an industrial setting. Rheocast Corporation in Natick is now producing some rheocastings on a production basis. I could cite many other examples: Professor Roy Kaplow's work on medical applications of shape memory alloys; Professor Robert M. Rose's work, with Professor Margaret MacVicar of the Department of Physics, on the development and processing of superconducting materials; the work which Professors Morris Cohen and Walter S. Owen are doing on the development of unstable austenitic steels for applications which require large damping of acoustical or elastic vibrations; and there are many more.

To carry out these projects successfully, it is necessary to employ a staff of professional research workers to provide continuity and a base of expertise, and to supplement the efforts of graduate students working on thesis topics. Thus, at the same time as our graduate student population has increased, the number of postdoctoral students in the Department also has increased. At the present time, we have about 20 full-time research workers. I expect this number to increase in the next few years. Inevitably, when involved in research projects of this kind, a substantial part of the effort of the faculty members is necessarily absorbed by interactions with other members of the team, the sponsors, and industry. Thus, less time is available for the supervision of thesis students and a smaller number of students can be supported by such projects. This is probably the reason why the ratio of total research dollars to total number of graduate students in the Department has increased so sharply in the last few years. Nevertheless, I am firmly of the opinion that students who participate in these major engineering projects enjoy a much better educational experience in materials engineering than would have been possible under the system existing 10 years ago. We have, as a matter of policy, expanded our participation in major engineering projects as a part of our program to develop a modern approach to the teaching of materials processing and materials engineering.

FACULTY

Professor Arden L. Bement is on leave at the Advanced Research Project Agency of the Department of Defense. Professor Kenneth C. Russell, who returned last year to the

Department after a leave spent at the United Kingdom Atomic Energy Agency at Harewell, is teaching some of the courses which Professor Bement developed specifically for nuclear engineering students. This joint activity with the Department of Nuclear Engineering is progressing very well. Professor John W. Cahn is spending a leave at the National Bureau of Standards.

Professor Bowen was appointed to a tenured position and simultaneously promoted to full professor. This unusual pair of events was well-deserved recognition of the excellence of the work which he is directing in the processing of ceramics and of his effectiveness as a teacher. We were pleased also that the Institute awarded tenure to Professor Heather N. Lechtman, who holds a joint appointment with us and the Department of Humanities.

We added two assistant professors to the faculty, bringing the number in the Department to six. Professor Thomas W. Eagar did his graduate work at M.I.T. under the supervision of Professor Rose. He spent some time at the Homer Laboratories of the Bethlehem Steel Corporation before returning to us to help with the teaching and research in metal processing, particularly in welding. Professor C.S. P. Sung did her doctoral work at the Polytechnic Institute in Brooklyn and worked for several years as a research associate with Professor Edward W. Merrill in the Department of Chemical Engineering at M.I.T. Her field is the structure-property relationships in polymers. She has a particular interest in electrical and optical properties of polymers.

During the period under review, the faculty continued to receive many honors and awards. These are listed under the individual faculty members' names in the Annual Data Book. Professor Owen was elected to membership of the National Academy of Engineering. Professor Cahn was awarded the Acta Metallurgica Gold Medal, the most prestigious international award in physical metallurgy.

Four years ago we decided to increase the number of untenured positions in the Department by decreasing the number of teaching assistants and increasing the number of assistant professors. It also was decided to replace faculty members who retire by untenured professors, except in rare cases in which we are convinced that a senior appointment is essential to maintain our leadership in a particular field. As a result, the proportion of our faculty who have tenure has decreased from 83 percent in 1975 to 73 percent in 1977. I expect that by next year it will have fallen to the percentage representative of the whole School of Engineering (67 percent).

WALTER S. OWEN

Department of Mechanical Engineering

Many exciting career opportunities continue to be open to mechanical engineers in such important areas as energy conversion and conservation, environmental engineering, biomedical engineering, transportation, and manufacturing. Further, the broad disciplinary background and design orientation of the field provides excellent preparation for careers in medicine, law, public policy, and management. These factors, in addition to the quality of the Department's faculty and programs, have made the Department increasingly attractive to prospective students. In 1976-77 the undergraduate enrollment increased even more than in the past four years of growth. A near doubling of the sophomore class to 125 brought the undergraduate body to 310, substantially exceeding the graduate school population (224) for

the first time in 30 years. While the graduate population remained stable (controlled primarily by available student financial support), the Department was more successful than in recent years in attracting the highest quality students in competition with other universities.

The organization of the Department in three major disciplinary Divisions, Mechanics and Materials, Fluid and Thermal Sciences, and Systems and Design, continued to be effective. The heads and associate heads of the Divisions were respectively, Professors Ali S. Argon and Nam P. Suh; Joseph L. Smith, Jr., and Ain A. Sonin; and David Gordon Wilson and Henry M. Paynter. The Steering Committee, consisting of the six faculty and the Department Head, advises the Department Head on matters of personnel, program development, and internal resource allocation, and helps to set Department policy and directions. The major research programs of the Department, although varied (reflecting the breadth of the Department) are concentrated primarily in four major programmatic areas: Energy and Environment; Biomedical Engineering; Manufacturing, Materials and Materials Processing; and Human Services including transportation.

The recommendations of the Departmental Planning Committee which completed its report in March 1976 were summarized in the 1975-76 annual report. During the past year several actions have been taken to implement these recommendations.

An ad hoc Graduate Curriculum Review Committee was appointed to conduct a thorough study of the graduate curriculum. Progress to date, described below under Graduate Program, includes: identification of a graduate "core," recommendation of a new graduate core subject in design which will be introduced next year, revision of a basic two-term sequence in the thermodynamics, abolishment of the foreign language requirement for the Ph. D. or Sc.D., and the recommendation of an English writing competency requirement for all graduate students.

A departmental plan was prepared for inclusion in the M. I. T. Leadership Campaign which after modification has been approved by the M. I. T. administration. This plan includes funds for the facilities developments recommended by the Planning Committee: a new Biomechanics and Rehabilitation Laboratory, a Center for Engineering Design, a Manufacturing Laboratory, an Interdepartmental Cryogenic Engineering Laboratory, and refurbishment of the Sloan Automotive and Gas Turbine Laboratories in Building 31. In addition, funds for curriculum development, undergraduate laboratories, and faculty chairs are included. If these resources can be raised they will enable the Department to fulfill much future potential which is now dormant owing to the heavy workloads, outdated facilities, and stringent operating budgets of recent years.

Funds for the Sloan Laboratory refurbishment have been committed and work will begin this summer under the direction of a School of Engineering Building 31 Committee.

The Biomechanics Laboratory in Building 3 was started on a modest scale last year and plans to complete the project are being prepared this summer by Physical Plant.

A major highlight this year was the formation of the Laboratory for Manufacturing and Productivity under the direction of Professor Nam P. Suh. This venture involves faculty members from the School of Engineering, the Sloan School and the interdisciplinary laboratories and centers, and provides a new focus for research and education in manufacturing. The Laboratory seeks to establish a rational foundation for manufacturing productivity increase by providing innovative methods and devices, a systematic understanding of the complex interactions among the many facets of manufacturing, and a renewed talent base for the field.

Undergraduate Program

The dramatic increases in undergraduate enrollment of the past two academic years were surpassed by a further growth of about 30 percent. This increase was primarily because the sophomore class nearly doubled this year while modest increases also occurred in the junior and senior classes. For the first time in nearly 30 years, undergraduates substantially outnumber graduates. At the current growth rate, the undergraduate enrollment will be about 375 in 1977-78 or approximately three times that of 1971-72.

This continued increase places growing pressures on the faculty and facilities of the Department, which have remained relatively static in recent years. An infusion of new equipment, more and refurbished space and -- of most importance -- additional junior faculty are essential to the continued quality of the Department's undergraduate program.

The reasons for the unusually large growth in undergraduate enrollment are complex but undoubtedly include such factors as: the increase in the size of the Institute undergraduate population; outstanding job opportunities for graduates in such expanding fields as energy, manufacturing and mechanical design; the breadth of mechanical engineering as preparation for careers in technical management, law, public policy, technology assessment, and medicine; and the quality of the undergraduate program.

Enrollment in the undesignated degree program (Course II-A) increased from 25 to 42 over the past two years. This program is centered in mechanical engineering but allows students freedom to define interdepartmental programs meeting their particular career objectives. Much of the growth in this program is attributable to student interest in biomedical engineering and medicine. The probability of admission to medical school for those undergraduates who apply remains virtually 100 percent.

Enrollment of women and minorities continues to parallel Institute trends.

Interest in Course II-B, the cooperative program with industry, grew substantially as indicated by a 50 percent increase in enrollment since last year. This program places students in industrial jobs during the summers following the sophomore and junior years. The growing interest in this type of program reflects the increasing orientation of students toward industrial careers.

Beginning in fall, 1977, Course II-B will be combined with a School-wide Engineering Internship Program which has been developed under the leadership of Associate Dean Ernest G. Cravalho. This program will involve six firms in its inaugural year with an ultimate goal of 20. The program will provide options for a terminal S.B. degree and a combined S.B./S.M. program, each with coordinated work and/or research experiences in industry.

This new program should foster closer ties between the Department and industry and add an important new dimension to the educational opportunities.

The undergraduate office, now in its fourth year of operation, continued under the capable direction of Professor Peter Griffith and his assistant, Peggy Garlick. The office is the focus for undergraduate matters, combining functions previously scattered throughout the Department: faculty teaching assignments (both graduate and undergraduate); communications between the Department and the Registrar's Office, the Schedules Office, and the Committee on Academic Performance; listing of job opportunities, coordination of UROP projects and undergraduate thesis topics; and support of the student operated Pi Tau Sigma course and instructor evaluations.

The Undergraduate Enrollment Committee, which is responsible for presenting the Department and its programs to prospective students, was continued under Professor David C. Gossard and Departmental Instructor Michael G. O'Callaghan. The committee organized several activities this year, including the Freshman Midway in September and departmental tours for prospective freshmen and sophomores. Both were well attended and favorably received. The committee also organized a "Mechanical Engineering Sampler" for the Employees' Open House. Many laboratories in the Department presented interesting displays which were attended by over 500 visitors.

Chaired by Professor Borivoje B. Mikic, the Undergraduate Committee, with its broad student and faculty representation, continued to provide a very effective policy forum for all matters concerning undergraduate life in the Department. This year the topics considered included grading policy in the Department, new restricted elective subjects, the effectiveness of various teaching modes, and the quality of the student environment.

Based on a thorough opinion survey among undergraduates, the following recommendations were made to the Department administration: 1) the restricted electives should be reviewed periodically by the Undergraduate Committee for relevance and quality and recommendations made for additions, modifications, or deletions; 2) a new restricted elective in Electromechanics should be offered; 3) the undergraduate body overwhelmingly recommends continuation of the recitation mode of instruction in the Department's core engineering science subjects.

The Undergraduate Laboratory includes four basic core subjects: 2.86 Manufacturing Processes Laboratory, 2.671 Measurement and Instrumentation, 2.30 Mechanical Behavior of Solids, and 2.672 Project Laboratory. All of these subjects involve extensive facilities, including machine tools, mechanical testing machines, electromechanical devices, and electronic and mechanical instrumentation. Because of the budget stringencies of recent years, much existing equipment is now outdated and subject to an increasing frequency of failures which frustrate students and in some cases present safety hazards.

The instrumentation situation was made more critical this year with an announcement by the National Science Foundation that the Instructional Scientific Equipment Grant would be available only once every three years. The Department was awarded \$11,500 from this grant in 1975, with matching funds from the Institute.

The Department was fortunate to obtain Edward Fischer as a new electromechanical technical instructor associated with the undergraduate laboratories. His responsibilities include teaching of instrumentation techniques, design of new experiments in courses 2.671 and 2.672, oversight of undergraduate laboratory equipment, and management of the Department's instrument room. Under the direction of Professor Adam C. Bell and with the support of Mr. Fischer, the two laboratories 2.671 and 2.672 are being integrated into a common location in the basement of Building 3. This integration will optimize utilization of space, instrumentation, and supervisory personnel while enhancing the quality of the undergraduate laboratory experience.

The quality of teaching in the laboratories remains excellent and student interest in these subjects continues to increase. New experiments were developed by Professor Griffith and O'Callaghan in 2.672 and by Professor Bell in 2.671.

Professor Richard H. Lyon restructured restricted elective 2.06 Vibration and Sound to take better advantage of the students' prior background in systems analysis and dynamics. The course will synthesize and build on concepts developed in the core dynamics subjects 2.02 Introduction to System Dynamics and 2.03J Dynamics.

Professor Carl R. Peterson will offer a new undergraduate seminar in fall, 1977, "Opportunities in Mining and Mineral Technology." It will cover the entire mining and materials industry, from the origin of ore bodies, through extraction (mining), the processing of the material and disposal of waste.

The four-course sequence in Environmental Ecology (2.131J and 2.132J Environmental Ecology I and II and 2.133J and 2.134J Environmental Problems Seminar) which was introduced last year by Professor Alician V. Quinlan in collaboration with Professor J. M. Edmond of the Department of Earth and Planetary Sciences, has been streamlined to two courses (2.131J and 2.132J). In 1977-78 these courses will emphasize topics primarily of interest to mechanical engineering students, including models of ecosystem structure and function, population dynamics, bioenergetics, and the dynamics and control of environmental pathologies.

The restricted elective 2.74 Advanced Mechanical Design was revised this year by Professor Gossard in collaboration with Professor Bell. The subject emphasizes the final stage in the design process: the reduction of a preliminary design to a manufacturable item. The intent is to provide students with design experience which reflects actual engineering practice. Among the topics covered are the selection and use of standard components, analysis of machine elements, design evaluation, optimization and engineering graphics and standards.

Undergraduates continue to be enthusiastic about design and the popularity of the undergraduate offerings in this area, including the elective 2.701 Drafting, is outstanding. This reawakening of student interest in design during the past few years (apparently a national trend) bodes well for industry, which needs more engineers skilled in the art of design.

Student Organizations

The Student Chapter of the American Society of Mechanical Engineers (ASME), under the leadership of its president, William J. Mazzei, Jr., provided undergraduates with an introduction to professional affairs and the ethical standards which ASME fosters. Professor Gossard was faculty advisor.

Pi Tau Sigma, the mechanical engineering honorary society, continued its tradition of service to the Department, the most valuable of which is the student evaluations of courses and instructors. This year the Society instituted biweekly student-faculty Friday afternoon parties which provided a friendly forum for discussion and relaxation. Robert D. Kneeland was President and Dean Cravalho served as faculty advisor.

BlackME, the society of black mechanical engineering students which was reorganized last year, continued as a means of providing tutoring, self-help, and improved communication among black students and faculty. James E. Hubbard served as the first president and Professor Stephen H. Crandall as faculty advisor. Plans were made to develop a library of study materials for the Departmental core subjects including quizzes, worked-out problem sets and notes, to be maintained by BlackME in the M. I. T. library for the benefit of all students. During the spring, morale of BlackME deteriorated because of lack of interest of many black students in the tutoring program and a sense of frustration of black seniors who were unable to secure financial support for graduate work. Thus a problem exists which must be addressed next year.

Graduate Program

Applications for graduate study decreased from 344 in 1975-76 to 331 this year. About half of the applicants were offered admission which resulted in 83 new graduate students being

registered. The total graduate enrollment is now 224 (232 including Special Students) and has been approximately constant for the past four years. This year the size of the graduate student staff -- research assistant, teaching assistant, and instructors -- reached 140, which is the largest in recent years. Some students view fellowships as more attractive than assistantships and this year fellowship grants to the Department from US industry increased to five from one last year. This is the result of our continuing efforts to develop closer ties between the Department and industry.

The Department awarded 60 master's degrees, seven combined S.B./S.M. degrees, six Mechanical Engineer's degrees and 24 doctorates in 1976-77.

Following a recommendation made by last year's Departmental Planning Committee, Department Head Herbert H. Richardson appointed a Graduate Curriculum Review Committee to review the graduate curriculum and make recommendations for changes in content and administrative procedures in light of the evolving requirements of graduate education in mechanical engineering. The Committee consists of a core group of three faculty members, one from each of the Department's three divisions, and an outer group of nine. An intense review was conducted during fall term within each division, coordinated by Committee members, but carried out primarily by small faculty groups and reviewed by the divisional faculty as a whole. Special emphasis was placed on the so-called core graduate subjects which cover, in graduate-level depth, the basic disciplines upon which mechanical engineering is based. Typically, these are the first courses taken by incoming graduate students, and usually make up a large fraction of the subjects most graduate students take in their first two years. These subjects also provide basic background for the doctoral qualifying examinations.

As a result of the review, several improvements in the curriculum have been recommended while further study is progressing. One notable change will be the introduction of a new graduate design subject 2.731 Advanced Engineering Design to serve as a core subject in graduate design and introduce students in a structured way to the design approach for which our Department has become known. This subject will be developed by Professor Bell and offered for the first time in spring, 1978. In addition, the two basic graduate subjects in thermodynamics 2.451J and 2.452J have been revised. The Committee also recommended that the departmental foreign language requirement for the Ph. D. be abolished, and that an English writing competency requirement be imposed on all graduate students. A one-term course for those whose abilities are unsatisfactory would be offered by the Department of Humanities. The foreign language requirement was formally abolished by faculty vote during spring term. The English requirement is still under discussion. It was also recommended that a committee be established to review the curriculum periodically and to identify gaps in content, opportunities for new developments, and make recommendations regarding teaching and staffing.

A new subject for spring term 1977 was developed by Professor Klaus-Jürgen Bathe, 2.093 Computer Methods in Dynamics, which covers the important details of finite element analysis of static and dynamic systems. Use of the existing general purpose analysis and computer programs, ADINA and ADINAT, developed by Professor Bathe and his colleagues is emphasized.

A new graduate area is being developed by Professor Peterson in 2.741 Fundamentals of Mining Technology, to be offered for the first time in fall, 1977. This subject will provide a basic background in the mechanics of mining operations. Emphasis will be on basic processes for mining rather than present methods, from the viewpoint of a mechanical designer.

In a related field, Professor Michael P. Cleary will offer a new subject, 2.074 Mechanics of Porous/Geological Materials, for the first time in fall, 1977. The objectives are to examine

the fundamental features of observed material behavior and to provide practitioners a basis for sensible design and analysis in resource recovery and geophysical investigation.

Professor James A. Fay introduced 2.63 Energy Production from Renewable Resources in 1976-77. This subject provides an analytical framework for evaluating the scientific, engineering, and economic feasibility of producing energy from renewable sources such as direct solar energy, wind, ocean waves and tides. Common aspects of renewable energy systems are emphasized such as variable nature, protection against extreme conditions and low energy fluxes.

Professor Lyon has made changes that will be effective in 1977-78 in the content of 2.066 Studies in Engineering Acoustics. The course will now provide an opportunity for individual and group study of specialized topics in applied mechanics and acoustics.

As a result of the graduate curriculum review, the basic graduate two-subject sequence 2.451J General Thermodynamics I and 2.452J General Thermodynamics II has been revised under the leadership of Professor Elias Gyftopoulos (Department of Nuclear Engineering). The sequence begins with classical thermodynamic principles followed by applications to the analysis and design of industrial processes and energy conversion devices. Theoretical developments are then extended to include chemical reactions and combustion, plasmas, rate processes, and quantum thermodynamics.

Instructor Andrew J. Rubel and his coauthor, Lecturer Roger E. Kaufman, won an Award of Merit for the best paper on "Practical Applications of Mechanism Theory" at the 14th ASME Mechanism Conference.

Mr. O'Callaghan will return to full-time doctoral studies next year under a Health Sciences Fund Doctoral Fellowship. He is working with Professor Cravalho on the preservation of biomaterials by reversible freezing and thawing.

RESEARCH

The total volume of sponsored research and the volume administered through the Department are projected to remain stable at approximately \$6.0 and \$3.7 million, respectively, reflecting strong continuing involvement of faculty in the research programs of the interdepartmental laboratories and centers, particularly the Energy Laboratory and the Harvard-M.I.T. Program in Health Sciences and Technology. Following a 38.6 percent increase in research support per faculty member from fiscal year 1975 to fiscal year 1976, this parameter remained approximately constant at \$120,000 in fiscal year 1977. This figure represents substantial effort by the faculty in the face of growing Federal paperwork, short-term support policies and shrinking support for university research. This level is close to the practical limit which the faculty can raise and manage without the addition of larger numbers of professional research staff -- a step which the Department is reluctant to take in light of its primary mission which is engineering education.

The shortage of discretionary funds for entering new fields of research -- to support research initiation by junior faculty and shifts of field by senior faculty, and to support basic disciplinary research not currently popular with Federal funding agencies -- remains a very serious problem. While no internal M.I.T. funds have been available to the Department to initiate new programs during the past academic year, a number of modest grants have been made directly to the Department by corporations and, in several instances, by individuals. In

the present budgetary climate such funds have been invaluable to the Department and typically have had leverages of one or two orders of magnitude in the development of new externally funded research programs.

In accord with the Planning Committee recommendations, research continues to be concentrated in four major programmatic areas: Energy and Environment; Biomedical Engineering; Manufacturing, Materials and Materials Processing; and Human Services including transportation. During the past three years the mix among these four areas has shifted, due in part to conscious encouragement by the Department. In relative terms biomedical engineering has decreased while manufacturing and human services have increased. The percent of faculty involved in energy and environmental research has grown from 43 percent to 50 percent; this area continues to be the largest of the four areas -- accounting for about 30 percent of the Department's activity -- due in part to strong coupling with the Energy Laboratory. Research funding through the Department in manufacturing, materials, and materials processing has grown from 19 percent to 24 percent of total departmental research during the same three-year period.

Basic research is also conducted in the fundamental disciplines associated with mechanical engineering although funding for such work is exiguous. Strong programs have been maintained in the mechanics of fracture and fatigue, in combustion and heat transfer, wear theory, constitutive relations for porous/granular materials, and element cycles in ecosystems.

New Programs and Notable Accomplishments

The most exciting development this year was the formation of a new Laboratory for Manufacturing and Productivity under the direction of Professor Suh. Drawing on faculty and staff from the School of Engineering, the Sloan School of Management, and the interdepartmental centers and laboratories of M.I.T., the Laboratory provides a new focus for research and education in manufacturing. The Laboratory is seeking to establish a rational foundation for manufacturing productivity increase by providing innovative methods and devices, a systematic understanding of the complex interactions among the many facets of manufacturing, and an important talent base of bright young people in manufacturing.

Proposals for several specific research programs have been submitted to funding agencies and substantial support is expected for the coming academic year. Among the new programs are computer aided manufacturing of formed parts, development of axioms for maximizing manufacturing productivity, coupling of manufacturing facilities with geothermal energy sources, and productivity in the garment industry.

Several new energy related projects were initiated this year in collaboration with the Energy Laboratory including fluidized bed combustion of coal, research on cooling towers and hot air solar heating, liquid dessicant dehumidification, application of heat mirror films to develop more efficient light bulbs, and an investigation of waste heat disposal systems. Much of this work is under the direction of Lecturer Leon Glicksman.

The Sloan Automotive Laboratory was merged into a School of Engineering fossil fuel facility in Building 31 and was placed under the direction of the Dean of Engineering. Major improvements of the facility are under way to accommodate the growing needs of the Departments of Chemical Engineering (combustion of coal), Aeronautics and Astronautics (gas turbines) and Mechanical Engineering (fire research and internal combustion engines).

The Department's engine research continued strongly under the direction of Professors John B. Heywood and James B. Keck, with substantial support from Ford Motor Company as well as from the Energy Research and Development Administration and the National Aeronautics and Space Administration. Projects range from conventional spark-ignition engines to

advanced concepts, including three specific stratified charge engine designs and gas turbines. The thrust of this research is fundamental in character and is aimed at understanding the impact of fuel characteristics, heat transfer, fluid mechanics, and thermodynamics on combustion in practical machines. These programs have an overall goal of obtaining improved performance and fuel economy with reduced emissions in power plants typical of those found in transportation applications.

The Cryogenic Engineering Laboratory is conducting research in two exciting areas: superconducting electric generators and the preservation of biomaterials by freezing. Both of these programs have experienced major changes this year.

The program on superconducting electric machines (on which Professor Smith is one of the leaders) has the broad objective of demonstrating the feasibility of applying superconductors to the windings of rotating electric machines. Work which has been under way since 1967 entered a new phase this year with the start of a five-year program to demonstrate an advanced design superconducting generator under actual service conditions. The program is focused on the construction of an experimental machine which is substantially larger than the previously developed 3MVA unit. This research is a joint effort with the M. I. T. Electric Power Systems Engineering Laboratory.

With the availability of new and more extensive funding, the effort in cryobiology, under the direction of Professor Cravalho, has expanded substantially. The objective of the work is long-term preservation of living tissue and organs by controlled-rate freezing. The organ freezing program, which has been only a minor part of the overall effort, was intensified by the addition of new research staff. Work in modeling of the freezing of biomaterials and in the measurement of water permeability of membranes will also be accelerated. The technique developed by Professor Cravalho and his associates for preserving whole blood by freezing is now successfully used in clinical applications.

Professor I. V. Yannas and his research team have extensively developed a composite polymeric material for use as artificial skin to aid in the treatment of severe burns. Many of the ideas developed under this project have been incorporated into a patent application. The material in its present state of development already represents the best available skin substitute and has attractive commercial possibilities. In addition, Professor Yannas' group is perfecting a new design concept in blood compatible materials based on the structural protein collagen. The new materials have potential for use in structural applications in surgery.

The recently created Vehicle Dynamics Laboratory, under the direction of Professor David N. Wormley, was expanded considerably during 1976-77. Current research programs involve both advanced systems for future transportation and means of improving conventional ground transportation systems. Research on non-contacting suspension and propulsion systems, including air cushion and magnetic levitation, is continuing. Recently, increasing effort has been devoted to the problems of rail transport, especially in the area of lateral dynamics of freight and passenger rail vehicles to reduce derailment propensity.

Professor Quinlan is continuing the Department's traditional commitment to environmental engineering with her research in ecosystem dynamics. Of particular current interest are modeling the effects of toxic chemicals on ecosystems and the effects of scarce mineral resources on population dynamics.

Many of the Department's research programs are having important impacts on the outside world. The following are only a few examples:

In Manufacturing, a new type of cutting tool has been developed, through use of a special oxide surface treatment, which has a dramatically increased life. A new company, Surftech, has been formed through the M.I.T. Development Corporation to exploit this and related developments.

In biomedical engineering, the binaural range and directional aid for the blind now known as the Sonicguide is available commercially. The unit, developed by the M.I.T. Sensory Aids Center, is built into an eyeglass-like package worn by blind travelers. The internally powered electromyographically-controlled lower arm replacement, the "Boston Arm" is produced by Liberty Mutual Insurance Company. Cryogenic preservation of whole blood is now used clinically in the US and abroad, a technique developed by Professor Cravalho and his collaborators.

In the energy field, a novel periodic cooling tower using oil coated disks to virtually eliminate water loss in heat rejection from power plants has been developed and will be licensed for commercial use. Methods of designing optimum forced-cooling systems for underground power-transmission systems are in use by the utility industry leading to savings of millions of dollars annually.

In transportation, computer based design programs for the cost optimization of elevated guideway structures including the effects of vehicle/suspension dynamics and ride comfort criteria are widely used by architect/engineer firms and government agencies in the US and abroad. Studies of the impact of regulation on the automobile, especially in the area of emissions and fuel economy, conducted by the Sloan Automotive and Energy Laboratories have had a major influence on Federal policy in this area.

FACULTY

With the addition of seven new members, the Mechanical Engineering faculty has increased in size from 48 in 1975-76 to 51 in 1976-77. Twenty-seven professors, 12 associate professors (seven with tenure), 11 assistant professors, and one adjunct professor make up the faculty, about two-thirds of whom are tenured. The relatively small number of assistant professors and untenured associate professors represents a marked change in faculty composition over the last few years.

Two senior faculty members were elected to the National Academy of Engineering. Professor Crandall was cited for leadership in the theory, education, and practice of engineering mechanics, especially in random vibration analysis, while Professor Ronald F. Probst was recognized for contributions to the fields of hypersonics, rarefied gas flow, desalination and water purification.

Institute Professor Ascher H. Shapiro received the Lamme Award from the American Society for Engineering Education "...for excellence in teaching and contributions to the art of teaching; contributions to research and technical literature; achievements which contribute to the advancement of the profession; and engineering administration."

Professor Nathan H. Cook received the Education Award of the Society for Manufacturing Engineers.

Professor Heywood was named Richard Mellon Overseas Fellow at Churchill College, Cambridge University. While on leave this year, he worked on a text on internal combustion engines.

Assistant Professor Cleary won a Young Faculty Award of the General Electric Foundation in an Engineering School-wide competition for development of his teaching and research career.

Professor Bathe served as chairman of the US-Germany Symposium on "Formulation and Computational Algorithms in Finite Element Analysis" held at M. I. T. last August.

Professor Fay continued as Chairman of the Massachusetts Port Authority and served on several local and national boards concerned with the technology and policy of energy and the environment.

Professor Quinlan served as a lecturer in a workshop on water quality modeling for the river Nile and Lake Nasser in Egypt. The workshop was sponsored by the US Environmental Protection Agency and was held in Cairo and Aswan, Egypt. Professor Quinlan also continued as Arthur D. Little Assistant Professor of Environmental Sciences and Engineering.

Professor Giuliana C. Tesoro was Chairperson of the 1977 Gordon Research Conference entitled, "Polymer Combustion and Fire Retardance."

Professor Thomas B. Sheridan was appointed as a member of the Office of Technology Assessment, US Congress Task Force on Appropriate Technology. Professor Sheridan also served on several committees involved with technology and policy.

Staff Changes

Three new faculty members joined the Mechanics and Materials Division during the past academic year. Dr. Bell, who was Visiting Associate Professor in 1975-76 from the State University of New York at Buffalo, was appointed Associate Professor. Professor Bell was placed in charge of 2.671 Measurement and Instrumentation, and now has department-wide responsibility for undergraduate laboratory instruments. Professor Bell's research is in the area of manufacturing and design. Dr. Robert O. Ritchie joined the Division as Assistant Professor in January 1977. His current interest is in the mechanical behavior of materials, with particular emphasis on fatigue, fracture, and stress corrosion cracking of metals. Professor Ritchie is teaching undergraduate core subjects in the mechanical behavior of materials and will help develop graduate subjects in the same field. Dr. Nak-Ho Sung, who had been a Lecturer and Research Associate in the Department, joined the faculty as Assistant Professor. Professor Sung continued his contributions to the Polymer Processing Program and to the educational efforts of the Department. He participated in teaching 2.30 Mechanics of Solids, and collaborated with Professor Suh in the graduate subject 2.867 Thermo-Mechanical Processing of Polymers.

In the Thermal and Fluid Sciences Division, two new Assistant Professors were appointed. Dr. Peter W. Huber, who received his doctorate from our Department in 1976, was appointed in September. Professor Huber taught undergraduate thermodynamics and fluid mechanics, and collaborated with Professor Sonin in research on nuclear reactor swell-effects associated with nuclear plant accidents. Dr. William C. Unkel joined the Department as Assistant Professor in January from Stanford University. His training and experience span the fields of thermodynamics, fluid mechanics, electrodynamic, heat transfer, and chemical dynamics. He will teach courses in theoretical and applied thermodynamics, heat transfer, and fluid mechanics.

Dr. Derek Rowell, an electromechanical engineer and designer in biomedical engineering, was appointed Assistant Professor in the Systems and Design Division. Professor Rowell's current interests are in biomedical engineering, including sensory aids, telemetry, and computer aids to biomedicine.

The resignation of Professor Robert E. Stickney, who accepted a position in Costa Rica in the field of nutrition planning, was accepted with regret.

HERBERT H. RICHARDSON

Department of Nuclear Engineering

The Department of Nuclear Engineering, which has grown considerably in enrollment and research volume in recent years, deliberately curtailed further growth during the past year. The present program has reached a size that is limited by the faculty available and we now anticipate a period during which further growth will be modest and controlled by the permitted growth in faculty positions. Although the Federal government continues to support further deployment of light water reactors, the government's current positions on reprocessing and the breeder reactor have cast some uncertainty on the long-range future of nuclear power. To date, these government actions have had little negative effect on student interest, research support, and demand for nuclear engineers. All of these indicators of the strength of the profession continue to be strong. During the past year the number of well-qualified applicants for graduate training far exceeded the available openings; however, there was a modest (about 15 percent) decrease in the total number of applicants over the high of two years ago.

In addition to the Department activities relating to fission power, which involve about 60 percent of the Department effort, the area of controlled fusion is now about 30 percent of the total Department activity. The other areas of effort include biomedical applications of radiation and applied radiation physics.

This year the Department had a total enrollment of about 220 students. This included 150 regular graduate students, 35 special Iranian students, and 35 undergraduates in the sophomore and junior classes. At present there are 22 faculty members. During the year the Department granted 72 advanced degrees including 38 Masters of Science, 12 Nuclear Engineers, and 23 Doctorates.

In addition, two S.B.s were awarded in June, marking the first such degrees granted by the Department.

This was the second year of the special Iranian program. The two classes had a total enrollment of 35 students. Next year the program will phase out. Although there were a number of concerns when the program began and some initial problems were encountered, these were ironed out with a minimum amount of difficulty. This year the program has been running smoothly and eight of the initial class of 22 completed their S.M. degree by June while 13 others will complete their program during the summer.

The Department's undergraduate program is now in its second year with 15 sophomores enrolled. This is somewhat below our goal of about 25 per class. Considerable efforts were made to give the program more visibility in hopes of increasing the number in next year's sophomore class. In addition to the regular undergraduate program, our five-year program which offers an S.M. in Nuclear Engineering and an S.B. in another department, continues to be popular and we anticipate that next year about a dozen undergraduates will be choosing this option. The student-to-faculty ratio remains quite high. Presently there are about eight graduate students per faculty member and nearly two undergraduates per faculty member. This produces a heavy teaching and thesis supervision load for the faculty and is the reason that further growth in the student body of the Department will be limited.

The support for graduate students and their research continues to be a problem. This difficulty has been relieved somewhat by the high level of sponsored research the faculty members have been able to obtain. From a low of slightly over \$0.5 million in 1972-73, the volume increased to \$1.6 million in 1975-76, and this year reached nearly \$1.7 million. In addition the Department participates heavily in the activities of the Energy Laboratory and the Research Laboratory of Electronics. This research is not reflected in the \$1.7 million dollar figure and accounts for an additional \$0.5 to \$1.0 million dollars. These funds helped support the research of nearly 50 graduate students. The Department continues to benefit from more than a dozen traineeships from the Energy Research and Development Administration (ERDA). In addition, the Department continues to be fortunate to receive fellowship support from the General Electric Foundation, the Babcock and Wilcox Company, the Northeast Utilities Company, and the proceeds from the Theos J. Thompson Memorial Fund.

The academic program of the Department continues to undergo revision and updating. However, because of the major changes in Department subject offerings during the last two years, the changes this year have been mostly in updating the content of present subjects, with only a few changes in subject offerings. The growth of the fusion technology area, with strong support from ERDA, has brought the fusion and fission options closer together. This program addresses the difficult engineering problems that must be solved before fusion can become practical. The Department expertise in nuclear materials, and in heat transfer and fluid flow gained in fission oriented programs, has been of great benefit in attacking these practical fusion problems. In addition to fusion technology, the Department continues to have a strong plasma physics program. The curriculum development and instruction in this growing area is carried out by Professors Thomas H. Dupree, Lawrence M. Lidsky, Peter A. Politzer, David J. Rose, Louis S. Scaturro, Dieter J. Sigmar (on leave), and Dr. James T. Woo.

This year the subjects in reactor engineering were better integrated by updating and revising the subject content to better prepare students with the engineering background needed to cope with safety and other engineering problems in large modern nuclear power plants. Professor John E. Meyer further developed the instruction in the area of structures and has been coordinating this program closely with other engineering departments, particularly the Department of Civil Engineering. The professors responsible for the overall development of the engineering program are Professors Meyer, Michael J. Driscoll, Michael W. Golay, Mujid Kazimi, David D. Lanning, Neil E. Todreas, and Lothar Wolf.

Professor Gordon Brownell continues to offer subjects relating to nuclear medicine. These subjects have been integrated with the Harvard-M. I. T. Program in Health Sciences and Technology (H.S.T.) The Department is continuing its work toward more productive cooperation with the H.S.T. program. It is hoped that in the future cooperative research programs will be developed.

The Department continues to offer a number of very popular special summer programs attended by a wide spectrum of professional people involved in nuclear engineering. The 432 registrants in Nuclear Engineering special programs in summer, 1976 accounted for 24 percent of the registrants in all M. I. T. special summer programs. This enrollment exceeded that of any other Institute department. In addition to providing added income, these programs have proved to be a valuable method of establishing contacts between the Department and the various parts of the nuclear industry. The programs included 22.83s Physical Aspects of Nuclear Medicine directed by Professor Brownell and Drs. Brian W. Murray and Donald J. Hnatowich, 22.92s Energy for Energy Decision Makers directed by Professors Rose and Golay, 22.94s/95s/96s Nuclear Power Reactor Safety directed by Professors Todreas and Norman C. Rasmussen, 22.98s/99s Nuclear Fuel and Power Management - Principles and Methods directed by Professor Kent F. Hansen, 22.80s Principles of Controlled Fusion, and 22.81s Technology for Fusion Reactors directed by Professors Lidsky, Politzer, Rose, and Dr. Woo.

A number of members of the Department faculty have been working closely with the M. I. T. Energy Laboratory. This cooperation already has led to a number of research projects in the Department through the Energy Laboratory. Although the support of the Laboratory, especially in the preparation of proposals, has required considerable extra work for some faculty members, the Department feels that the potential benefits of this effort are large. Dr. William Hinkle of the Energy Laboratory staff works very closely with the Department and has developed an agreement between the Energy Laboratory and a consortium of local utilities that has sponsored a number of research projects in the Department. Such close ties with the Energy Laboratory broaden the Department's professional staff and are beneficial to both organizations.

RESEARCH

This year, as mentioned above, the research volume of the Department reached a new high of \$1.7 million. The major research activities included: Reactor Kinetics Project with Electric Power Research Institute by Professors Kent F. Hansen and Allan F. Henry; Rod-Drop Analysis with Commonwealth Edison by Professor Hansen; Development of Few-Group Parameters with Electric Power Research Institute by Professor Henry; Thermal Neutron and Light Scattering Studies with ERDA by Professors Sow-Hsin Chen and Sidney Yip; Neutron Molecular Spectroscopy with National Science Foundation (NSF) by Professors Chen and Yip; Static and Dynamic Structure of Dense Gases with NSF by Professors Chen and Yip; Computer Simulation Studies of Molecular Solids with Army Research Office by Professors Yip and Owen L. Deutsch; Frequency -- and Wavelength-Dependent Fluctuation in Fluids with NSF by Professor Yip; Coolant Mixing in Rod Bundles with ERDA by Professor Todreas; Fuel-Coolant Interaction with ERDA by Professor Todreas; Fusion Blanket Design with ERDA by Professor Todreas; Thermal Hydraulic Analysis of PWR with New England Electric System and Northeast Utilities (through Energy Laboratory) by Professor Todreas; Light-Water Reactor Core Design with Yankee Atomic Electric Company by Professor Lanning; Light-Water Reactor Thorium Utilization with ERDA (through Energy Laboratory) by Professors Driscoll and Lanning; Reactor Transient Code Analysis with Electric Power Research Institute by Professors Lanning, Wolf, Henry, Todreas, and Hansen; Fast Reactor Blanket Test Facility Program with ERDA by Professors Driscoll and Lanning.

Other major research activities included: Fuel Performance Analysis during Normal Transient Conditions with New England Electric System and Northeast Utilities (through Energy Laboratory) by Professor Meyer; Cooling Tower Drift Elimination with New England Electric System and Northeast Utilities Service (through the Energy Laboratory) by Professor Golay; Waste Heat Disposal with Electric Power Research Institute and Battelle Northwest Institute by Professor Golay; Reactor Accident Risk Analysis with Sandia Corporation by Professor Rasmussen; Plenum Mixing Project with ERDA by Professor Golay; Boiling-Water Reactor Heat Transfer Code with New England Electric System and Northeast Utilities Service (through Energy Laboratory) by Professor Wolf; M. I. T. Total Energy Analysis with M. I. T. by Professor Golay; LWR Assessment Program with ERDA by Professors Rose, Golay, Lanning, Driscoll, Wolf, and Rasmussen; Total Energy System for Large Military Installations with US Army by Professor Golay; Thermal Hydraulic Sensitivity Study with Electric Power Research Institute by Professor Wolf; Temperature Fields in Liquid Metal Fast Breeder Reactors with ERDA by Professor Wolf; Fusion Technology with ERDA by Professors Lidsky, Politzer, Woo, Scaturro, and Rose; Applied Plasma Physics with NSF and ERDA by Professors Lidsky, Politzer, and Scaturro; Creep Behavior of Zircaloy with Electric Power Research Institute by Professor Arden Lee Bement; Nuclear Techniques in Bone Disease with National Institutes of Health by Professor Brownell and Drs. Murray and Hnatowich; Fibrinogen Detection with Health Sciences Fund by Professor Brownell and Dr. Murray; Os-Ir Generator

with National Institutes of Health by Dr. Hnatowich and Boron Capture Therapy with National Institutes of Health by Dr. Murray and Professor Brownell.

Activities Outside the Department

Department of Nuclear Engineering faculty continue to be active outside the Department, in both M. I. T. non-departmental activities and a variety of activities outside M. I. T. for professional societies and government agencies.

Professor Rose is a member of the steering committee of the National Academy of Sciences Committee on Nuclear Alternative Energy Sources. He continues to serve as an advisor to the Office of Science and Technology Assessment on matters concerning Federal energy budgets. He served as a member of the Organizing Committee for the American Association for the Advancement of Science Workshop on Adapting Science to Social Needs. The World Council of Churches continues to use Professor Rose as a participant in their study on energy. This year he completed service on the Massachusetts Governor's Advisory Committee on Nuclear Energy. In addition to this, he has given numerous talks on energy options, including two appearances before Congressional committees. Professor Hansen continued to chair the Committee on Engineering Education of the School of Engineering. This important committee is studying ways of improving the efficiency and effectiveness of engineering education at M. I. T. Professors Chen and Yip serve as advisors to the government of the Republic of China. Professor Henry continues his work as a member of the Advisory Committee on Reactor Physics for ERDA, and also as a member of the editorial advisory board of Nuclear Science and Engineering. Professor Driscoll was elected chairman of the Reactor Physics Division of the American Nuclear Society. He also was appointed to the visiting committee of the Nuclear Engineering Department of Lowell University. Professor Driscoll also serves on the ERDA Committee including the Sodium Boiling Working Group, Heterogeneous Liquid Metal Fast Breeder Reactor (LMFBR) Core Evaluation Team, and the Large Core Computer Code Evaluation Working Group. Professor Todreas continues as chairman of the American Society of Mechanical Engineers Heat Transfer Division's Committee on Nucleonics. Professor Meyer was elected secretary of the Mathematics and Computation Division of the American Nuclear Society.

Professor Elias Gyftopoulos continues to advise the Greek government in the role of chairman of the National Energy Council of Greece. He also serves as a member of the Energy Task Force of the Commission of Socio-Technical Systems of the National Academy of Sciences. Professor Golay was elected chairman of the Northeastern Section of the American Nuclear Society (ANS) and a member of the ANS Standards Committee, and secretary of the Environmental Science Division of ANS. He is also a member of the American Society of Mechanical Engineers Environmental Heat Transfer Committee. Professor Irving Kaplan completed his second year as Secretary to the M. I. T. faculty. He remains an active participant in the Technology Studies Program. Professor Manson Benedict served on the ERDA Liquid Metal Fast Breeder Reactor Review Steering Committee. Professor Otto K. Harling continues his responsibilities as director of the Nuclear Reactor Laboratory. Professor Rasmussen continued his service on the Defense Science Board. He was appointed to the review committee of the Argonne National Laboratory Division of Component Technology. He continued to give talks in the US and foreign countries to explain the results of the Reactor Safety Study and nuclear power.

FACULTY

Professor Edward A. Mason who was on leave as a commissioner of the Nuclear Regulatory Commission resigned from the Department to accept a position as vice president for research at Standard Oil of Indiana. Professor Mason had been with this Department from its inception and contributed importantly to its growth and development. He will surely be missed. Professor Hansen has been appointed by President Carter to the Nuclear Regulatory Commission; he will begin a two-year leave of absence next year. Dr. Mujid Kazimi was appointed Assistant Professor. Professor Bement continued his leave of absence as Director of the Materials Research Program of the Defense Advanced Research Projects Agency. Professor Sigmar continued his leave of absence at the Oak Ridge National Laboratory.

Honors and Awards

Several of the Department faculty were recognized with honors. Professor Brownell received the Paul C. Abersol Award of the Society of Nuclear Medicine. Professor Benedict was elected to the American Philosophical Society. Professor Rose received the Outstanding Teacher Award of the M. I. T. Student Chapter of the American Nuclear Society. Professor Rasmussen received the Distinguished Service Award of the Nuclear Regulatory Commission and was also elected to the National Academy of Engineering. In October Professor Benedict was one of 15 recipients of the National Medal of Science.

NORMAN C. RASMUSSEN

Department of Ocean Engineering

Ocean industries in the United States and abroad continue to offer challenging opportunities to graduates of the Department of Ocean Engineering. Most find employment in industries connected with commodity transportation, and increasing numbers are attracted to the offshore petroleum industry. Through its teaching and research programs, the Department prepares students as well for careers in the defense industry, and in the new ocean minerals industry. Also, a significant number of the Department's graduates find career opportunities in government service relating to the management and use of the oceans and in government or private sector research laboratories. All students are encouraged to follow programs that span elements from engineering science to socioeconomics, since appropriate engineering for the oceans must include concern for general societal interests as well as for physical factors.

Academic Highlights

Enrollment this past year stood at an all-time high, with a total of 200 regular students in spring, 1977. This is the fourth year in a row in which the total enrollment has been close to this level. In comparison with the previous year, the undergraduate enrollment increased by nine, while the graduate enrollment decreased by eight. We expect total enrollment to remain at this level or to increase somewhat during the next several years.

Enrollment in the Department's Cooperative Work-Study Program (Course XIII-C) is still relatively small. This is so in part because the total undergraduate enrollment is small, and in part because a small department such as this cannot always allocate sufficient human and financial resources to solicit and negotiate with candidate cooperative companies. In this light, we are pleased to note that the School of Engineering is planning to begin a similar program on a School-wide basis, with the intent of sharing administrative and planning functions among several departments.

Many of us view cooperative education as a model for the future, in the sense that the majority if not all undergraduate students would be in such a program. The rising price of education is one reason for this belief. Through a work-study program, financial burdens tend to be eased significantly. More importantly, many of us believe that work experience as part of the undergraduate effort is desirable for most, if not all, students.

For three-quarters of a century, the United States Navy has encouraged its best engineering duty officers to obtain graduate education in the Department. At present, approximately 40 officers are enrolled in a three-year program leading to the degree of Ocean Engineer. During the past year, we have studied with the United States Navy the career needs of such officers and have come to the following conclusions:

There is a need for both a two- and a three-year program in the Department for engineering duty officers. As at present, the three-year program would lead to the Ocean Engineer while the two-year program would place candidate engineering duty officers in the Department's Master of Science program.

Navy billet requirements substantiate a need for approximately 10 to 15 graduates per year from the Ocean Engineer program and, as well, 10 to 15 graduates per year from the Master of Science program. At present, we graduate approximately 10 to 15 per year from the Ocean Engineer program only.

The United States Navy has established a goal of increasing its level to 25 to 30 accepted graduate student officers per year within the next three years. This is some 10 to 15 more than the present level.

RESEARCH

Since 1971-72, sponsored research funds available to the Department, in constant dollars, have decreased both in total and per individual principal investigator. This past year, however, we are pleased to note a sharp change in this trend which places our research funding up to the 1971-72 level. Research funds are vital in maintaining a program that is both forward-looking and broad. Such funds are also important in providing research assistantships, which in turn relate closely to the size of the graduate student body. Data available to us at present suggest that we can expect to maintain or slightly increase this new level of research funding into at least the next year.

The Department's research program continues to reflect the broad field of ocean engineering. Some new projects which indicate our breadth of interests are: analysis of the structural failure of Chester Polling, which went down in the Gulf of Maine off Cape Ann this past winter; experiments on cavitation in propellers and hydrofoils; laboratory experiments on, and systems analysis of, energy extraction from ocean surface waves; field experiments in the Arctic Ocean on acoustic reverberation from basin boundaries; and analysis of management alternatives for fin fisheries within the new 200-mile economic zone.

Acquisition and implementation of a laser doppler system for velocity measurement marks a major increase in capability of the Department's Variable Pressure Water Tunnel. The equipment is already in extensive use for a variety of projects including measurement of fluctuating flow fields in the vicinity of a propeller, demonstrations of boundary layers and separated flows, measurement of simulated ship wake fields, and measurement of velocity distribution around hydrofoils.

FACULTY

Dr. Clark Graham, previously Associate Professor, has been appointed Adjunct Professor. Dr. Graham held his appointment as Associate Professor on a full-time basis, on assignment by the United States Navy in the Department's Course XIII-A. Upon return to Navy duty last year, we were able to arrange for Dr. Graham's continuing services as an Adjunct Professor. His specialty is ship design.

Professors Norman Jones and Jerome H. Milgram, presently Associate Professors, will assume the rank of full Professor on July 1, 1977. Associate Professor Arthur B. Baggeroer will achieve academic tenure, also on July 1, 1977.

Professor Baggeroer spent fall term on sabbatical at Woods Hole Oceanographic Institution to continue research in detection and estimation theory, array processing, and ocean seismic and sonar systems. He spent spring term in La Spezia, Italy, working at the NATO SAACLANT Center studying long-range acoustic propagation in the seabed.

Professor Judith T. Kildow is on leave at the University of California at San Diego in their Department of Political Science. She is teaching and doing research in marine policy and ocean utilization.

Professor Henry S. Marcus was on leave during fall term with Temple, Barker, and Sloan, Inc., to develop an interactive computer model to forecast fleets serving the United States international trade during the next 25 years.

The Department had a large number of visiting staff this past year. Professor Torgeir Moan of the Norwegian Institute of Technology, Trondheim, Norway, stayed through fall term to assist with the Department's structures curriculum. Ferdinando Laudiero of the University of Naples participated with Professor Norman Jones in his structures research. Dr. Hironori Ozaki, from Kawasaki Industries of Japan, participated in welding research with Professor Koichi Masubuchi.

Three visiting scholars were with us this past year. They were Dr. Cengiz Dokmeci of the Technical University of Istanbul, Turkey, Dr. Edward Klocek of the University of Gdansk, Poland, and Werner Hansmann of Ruhr-University, Bochum, West Germany.

Professor John W. Devanney III has coauthored Parable Beach: A Primer in Coastal Zone Economics, M.I.T. Press, 1976.

Awards and Honors

Professor Chyrssostomos Chryssostomidis received the Captain Joseph Linnard Award of the Society of Naval Architects and Marine Engineers for the best technical paper presented before a local section.

Professor Devanney was chosen to give the keynote speech to the 1977 Annual Meeting of the Independent Tanker Owner's Association (INTERTANKO). Only one other academic has been so honored in the history of the Association.

Professor J. Harvey Evans was awarded the Davidson Medal in November 1976 by the Society of Naval Architects and Marine Engineers for "outstanding scientific accomplishments in ship research."

Professor Patrick Leehey was named the recipient of the Fulbright-Hays award for lecturing at the Technical University, Graz, Austria, 1977-78.

Professor Masubuchi received an award in December 1976 from the American Society of Mechanical Engineers for the best paper published in 1975 in the Materials Division. He also received the R. D. Thomas Memorial award for 1977 by the American Welding Society.

HART NAUTICAL MUSEUM

The winter of 1976-77 focused public attention on heating problems and fuel supplies, and brought unusual activity to the Hart Nautical Museum following the stranding of the Liberian registered petroleum tanker Argo Merchant which subsequently broke up on the Nantucket Shoals. As the only source of tanker information in the region, the museum provided material to two Boston television stations while the Providence station WPRI (Channel 12) sent a crew to photograph tanker models and other items from the museum's collection.

In October 1976, the museum received as a gift from Basil Greenhill, Director of Britain's National Maritime Museum, four volumes containing plans, photographs, and descriptions of vessels built in the Denny shipyard at Dumbarton, Scotland. These volumes are of particular interest to M. I. T., for a former apprentice who rose through the design office to become yard manager of Denny's during World War I was Professor James Robertson Jack, second Head of the Department from 1919 to 1936 (then known as the Department of Naval Architecture and Marine Engineering). M. I. T. students who took Professor Jack's courses were quite familiar with the ships from the Denny yard, many of which he had designed.

Other gifts during the past year included a color print of the British tea clipper Cutty Sark framed in teak taken from her deck, and a number of books. The second, enlarged edition of The National Watercraft Collection was purchased for the book collection.

In turn, the Hart Nautical Museum made a gift of 17 photoprints from Professor George Owen's yacht design files to the new Kingston Marine Museum at Kingston, Ontario, Canada. Many yachts designed by Professor Owen are still sailing on the Great Lakes and there is considerable interest in restoring them. Plans for the W. Starling Gurgess designed Brutal Beast were supplied for building a number of boats for the Metropolitan District Commission Pleasure Bay Sailing Program, sponsored by the Boys Clubs of Boston. As in previous years, reproductions of plans and photographs were furnished to a large number of inquirers seeking information for the restoration of yachts, construction of models, or for study purposes.

During the past year, school groups from Hingham, Massachusetts, and Kingston, New Hampshire, were given special tours of the museum's display area. A number of students from the Department of Ocean Engineering and other departments in the Institute have received assistance with various projects and the curator is working with a doctoral candidate in maritime history from Boston University. One of the more interesting projects was that of

a candidate for an S.M. in Architecture, "The Architecture of Ocean Liners," for which most of the material came from the museum's files.

IRA DYER

Center for Advanced Engineering Study (C.A.E.S.)

During the 1976-77 academic year, C.A.E.S. continued to provide and expand its academic programs to mid-career professionals from industry, government, and academic institutions of the United States and foreign countries. There are on-campus fellowship programs designed to meet individual needs; off-campus study through distribution of videotaped subjects; and off-campus study for credit through videotaped/tutored graduate subjects. C.A.E.S. has instituted plans for a program of short courses and seminars. The Center continued to provide video services to the Institute through television instruction and production; video equipment rental; a cable television system; and support for various research and service projects in the Institute. The Center continues under the direction of Myron Tribus, Professor of Engineering; Jack Newcomb is the Assistant Director and Linda Ward is the Business Manager.

ON-CAMPUS PROGRAMS

Advanced Study Program

The on-campus education programs of the Center, under the direction of Paul Brown, provide experienced men and women the opportunity to pursue studies tailored to their needs and the objectives of their employers or sponsors. On-campus programs include the Advanced Study Program, the Advanced Study Program in Air Transportation, the Advanced Study Program in International Nutrition Planning, and the Education for Public Management Program.

In addition to making available regular graduate and undergraduate subjects and seminars, opportunities to participate in ongoing research, and opportunities to do special studies guided by one or more members of the faculty, C.A.E.S. offered 10 special subjects and a weekly seminar specifically for the Fellows, and orientation programs on computer programming. During the summer the Center also offered a six-week intensive review of mathematics for incoming Fellows.

This year the number of Fellows was 50, six less than last year. They came from 22 countries in addition to the United States. Seventy percent of this year's Fellows came from foreign organizations which is about the same fraction as last year. Forty-four percent of those from US organizations were from industry. Forty of the Fellows were in the Advanced Study Program, three less than last year.

C.A.E.S. offered the Education for Public Management Program jointly with the Department of Political Science. An academic year-long program for mid-career Federal employees, it attracted six Fellows, three less than last year.

The Center offered the Advanced Study Program in Air Transportation jointly with the Flight Transportation Laboratory of the Department of Aeronautics and Astronautics but enrolled only one Fellow. This Program is still in the process of being established.

The Advanced Study Program in International Nutrition Planning, offered jointly with the Department of Nutrition and Food Science and the Center for International Studies, enrolled three Fellows, the same number as last year.

The Programs were educationally successful in that they enabled Fellows to meet their needs and objectives and were financially successful in that they broke even. The income for the year was approximately \$300,000. Of this, approximately \$120,000 was a transfer to Institute General Funds for tuition for regular subjects attended by Fellows. The program also supported three teaching assistants and one research assistant during fall term and four teaching assistants during spring term. Support of teaching assistants included tuition awards. The Program also paid part of the salaries of six professors. (Approximately 1.4 equivalent full-time faculty member).

An advantage of the very flexible format of the Advanced Study Program is that other more specialized programs can be started under its auspices. For instance, the Air Transportation Program and the International Nutrition Program do not need to stand on their own with just a few Fellows. These Fellows mix with and attend many of the same C.A.E.S. seminars and special subjects as Fellows in other Advanced Study Programs.

OFF-CAMPUS PROGRAMS

Self-Study Program

The Self-Study Program, under the direction of John Fitch, produces and distributes videotapes, 16mm films, and study guides in engineering, science, mathematics, and management. These now comprise more than 500 modules of non-credit instruction. Although developed primarily for the continuing education of practicing engineers and scientists in industry and government, the materials are finding increasing use in undergraduate and graduate courses at other colleges and universities.

After six years of losses, the self-study program has begun to return money to the Center. Revenue for the past year was more than \$300,000, a three-fold increase over the previous year, resulting in a net return of approximately \$100,000. This dramatic turn-around in the fortunes of the program is due, we feel, to the revised marketing program instituted in late 1975 and continued during this past year. The emphasis has been on a modular rather than a complete subject approach to the materials and an extensive use of direct mail rather than personal contact. Because of the growth of the sales promotion effort and the volume of order processing that has resulted, we have added two new members to the program staff: Katherine Potter has been appointed Administrative Assistant and Rose McMaster Sales Secretary.

The Center now produces a yearly 120-page catalogue which is mailed to 12,000 recipients. In addition, several smaller mailing pieces, describing individual subjects, are mailed to another 35,000 potential users. We also have begun to develop a network of commissioned representatives and commercial publishers; although these have not yet produced any

significant income, we feel that they represent a valuable potential source, particularly in the international market.

Because of past financial strictures, no new materials were produced by C. A. E. S. during the year. Several subjects were added to the catalogue, however, by acquisition. In this connection, the Dean of Engineering has appointed an advisory board to aid the Center in judging the suitability of such acquisitions. In the year to come, we intend to underwrite new production. We have already begun negotiations with several faculty members for the development of additional self-study subjects.

Tutored Video Instruction (T.V.I.)

Tutored Video Instruction began at M.I.T. with a small program for spring term, 1977. Three Electrical Engineering subjects -- 6.082 Switching Circuits, Logic and Digital Design; 6.333 Electronic Circuits, and 6.611 Introduction to Optical Electronics -- were offered at one of three locations: Analog Devices (Norwood), Analog Devices Semiconductor (Wilmington), and Raytheon (Sudbury). Many of the students had advanced degrees, and were interested in increasing their own technical competence as well as applying the new material to their work. The response of the industrial students was very positive. They uniformly said that they had to work very hard but felt the results were worth their efforts.

In the T.V.I. program, videotaped lectures from M.I.T. are delivered, often within 24 hours, to places where engineers are employed. Groups of four to nine students watch the tapes under the supervision of an M.I.T. appointed tutor, selected from the company. The tutor has been taught to stop the tape at frequent intervals and lead discussions. The tutor also identifies company related technical problems and serves as the link to the on-campus staff. Students receive the same homework and quizzes that regular students receive and have their work corrected and graded as though they were on campus.

There are two video cameras in the on-campus T.V.I. classroom. One camera at the front of the room is directly overhead and is focused on the desk where the professor writes equations or exhibits prepared material. The second camera is in the back of the room and can be focused on the professor or on the blackboard. On-campus students in the classroom view the written material on video monitors located throughout the classroom.

In the large lecture halls a single video camera is focused either on the professor or on the blackboard. The quality of the lecture hall tapes is also excellent because the professors write large, legibly, and in the 3 x 4 aspect ratio of the camera.

There are three categories of students: Listeners, Special Students, and Regular Students. Listeners participate fully in the tutored groups but do not have their homework corrected, do not need to take quizzes, and do not receive academic credit. Special Students are those studying to obtain academic credit but not enrolled in an M.I.T. degree program. Special students have their homework graded and take quizzes just like the on-campus students. Regular Students have been accepted by a department for study toward an advanced degree. Since M.I.T. requires a thesis for an advanced degree in engineering, the number of Regular Graduate Students is limited by the number of thesis candidates who can be properly supervised at any one time. Admission to a degree program is highly competitive.

All categories of students receive a copy of the homework, homework solutions, quizzes, quiz solutions, and any other class handouts.

Approximately eight subjects will be offered via T.V.I. for fall term, 1977. We hope to enroll at least five tutored groups per subject, giving a total enrollment of more than 250

students. Based on our previous experience, we anticipate that most of these students will be enrolled on a non-credit basis.

Part of our planning for the future includes investigating how continuing engineering education is utilized in industry. We hope to determine, in addition, what the long-term needs of engineers in industry are and how M.I.T., through the Center for Advanced Engineering Study, can meet those needs.

CABLE AND VIDEO SERVICES

The Cable and Video Services provide a service function throughout the Institute, subsidized partially by M.I.T. and partially by a developmental program sponsored by the Alfred P. Sloan Foundation. The regular routine includes: 1) serving the C.A.E.S. Self-Study Program by producing and duplicating tapes; 2) serving various departments with rental equipment and services; 3) collaborating with research staffs on specific video and cable T.V. projects; 4) recording events of interest to the M.I.T. administration; 5) supporting, teaching, and encouraging faculty, students, and employees in the use of video and cable in education; and 6) serving those who have received support under the second video and cable grant from the Sloan Foundation.

Last year, the Alfred P. Sloan Foundation awarded M.I.T. a follow-up grant of \$490,000 to encourage the use of video and cable in education. That grant is administered in C.A.E.S.

There are 3.5 full-time personnel in charge of the equipment, studios, and facilities.

The Director and Staff of C.A.E.S. have been pursuing a four-point strategy which may be described as follows: 1) to provide equipment and facilities which are easy, inexpensive, and convenient to use; 2) to provide the human resources required to assist professors and research staff in producing the materials they wish to present; 3) to provide encouragement and assistance to professors and administrators who wish to use the facilities for their purposes, and to work with those who might wish to develop proposals for funding video activities; 4) to develop a pricing scheme and, if necessary, proposals for Institute subsidies, which would make the system viable in the M.I.T. environment.

In a sense, the equipment list is never filled, for as rapidly as facilities are acquired, new technologies and more advanced techniques are developed and a new "wish-list" is developed. However, it can be said that M.I.T. now has some of the finest equipment available in an educational institution and does not seriously lack hardware except for some specialized purposes (i. e., 3/4-inch cassette edit or broadcast quality portable color cameras).

As of now, we have a number of facilities in operation. These include a broadcast quality, two-inch video facility, editing and viewing facilities, a rental service for remote productions, and a television classroom. The latter has been used for the Tutored Video Instruction Program. It seats 40 students, and contains 20 monitors and a specially equipped instructor's desk. The facility cost \$30,000 and will be used to produce two subjects this year. From five to 10 tapes may be made simultaneously. Two black and white cameras are controlled by a student operator. We have instructed personnel in various departments who are able to give video instruction.

During workshops, care and basic operation of equipment is taught, and hands-on familiarity is encouraged. When people begin projects on their own, they encounter problems requiring individual attention, therefore the C.A.E.S. staff becomes very busy in one-on-one instruction as each term progresses.

The result of this activity is that there is now a pool of about 100 users who are familiar with the equipment and can use the facilities at varying levels of expertise. There are about 40 persons capable of using the small color studio, and this number is increasing rapidly.

We have assisted the following departments and faculty members in their educational activities:

Professor Wesley Harris -- An experiment has been planned to try tutored video instruction with disadvantaged students this term.

C. A. V. S. (Aldo Tambellini) -- Production of live and taped material for the cable. The "Image Manipulation" course at C. A. V. S. produced a live, weekly show for the cable with full C. A. E. S. support.

UROP -- We assist UROP in producing tapes and live shows on the cable on student research projects.

Department of Humanities (Professor Albert R. Gurney) -- We provide facilities and equipment for two drama classes, Acting for Television and Design for the Performing Media.

Department of Humanities (Dan d'Hainaut) -- We assist the Writing Program with facilities and equipment for class and individual projects.

Department of Humanities (Professor David Thorburn) -- We are helping to develop proposals for support of his research on network programming as an indigenous art form, and are lending equipment and facilities.

Department of Urban Studies and Planning (Professor Thomas Nutt-Powell) -- Production of two broadcast level pilots on energy planning and conservation.

Department of Architecture (Professor Richard Leacock) -- A live weekly cable show, "24 - 30 FPS," featuring discussions with filmmakers and examples of films and videotapes produced at the M. I. T. Film Section.

Professor E. Parzen -- Professor Herman Chernoff of the Department of Mathematics requested this program, "Time Series Methods in Non-Parametric Theory," to be carried live from Harvard on the M. I. T. cable, with two-way audio communication.

Department of Electrical Engineering and Computer Science (Professor James R. Melcher) -- Weekly live homework sessions for 6.013 Electro-Magnetic Fields and Energy. He also used the cable for showing films and tapes, e. g. "Electromechanical Dynamics of Synchronous Machines by Herbert Woodson.

Department of Electrical Engineering and Computer Science (Professor Alvin W. Drake) -- Quiz Reviews for 6.041 and 6.431.

Professor Myron Tribus, Director of C. A. E. S. and Professor of Engineering -- Cablecast his lecture series "Thermostatics and Thermodynamics" for 10.13 Mass and Energy Processing and for I. A. P.

The Libraries (Jay Lucker) -- Viewing facilities were extended and a pilot on "technical translations" was produced.

Department of Mathematics (Professor Gian-Carlo Rota) -- Lecture series for Concourse: "The End of Objectivity."

Department of Civil Engineering (Professor James Becker and the Design Case Study Group) -- Taped and edited an intricate documentary on an office building, 60 State Street, called "60, 46, 37 HUT."

Edwin Diamond -- Did two weekly live shows on the cable. There were cablecasts of "Rhetoric and Journalism" (21.940) and "Politics and Television" (17.27).

Department of Urban Studies and Planning (Professor Lawrence Susskind) -- A video experiment was conducted with the Citizen's Involvement Committee.

In addition to use of the cable by M. I. T. faculty, we made arrangements to cablecast lectures at the Harvard University School of Medicine. These included the Edward K. Dunham Lectures for the Promotion of the Medical Sciences.

All student projects have received full support from C. A. E. S. for use of equipment and facilities. Some of the regular student video groups are Video Club, MITV, Basement Video, and Communications Workshop.

The Cable also has been used for Institute events like Orientation, the United Way drive, the Martin Luther King Memorial, and the "World Change and World Security" lecture series.

More than half the video work at C. A. E. S. is supported without any cash exchange. It is either "in-kind" support for a funded project, or a "credit account" for low-budget projects by students who produce regular cable programming.

CAM PROJECT

Under a grant from the National Science Foundation, the Center has begun planning a series of videotapes and study guides on Computer Aided Manufacturing (CAM). This program, undertaken with the cooperation of the Draper Laboratory, will provide a short series of management-level videotapes which survey the field on an international basis, and a longer series of self-study videotapes and study guides which aim to provide working engineers with state-of-the-art information about current research. Much of the material for the first series will be derived from a one-day symposium to be presented by the Center in September 1977, and much of the material for the longer series will be obtained from a three-day conference of Research Applied to National Needs grantees presented by the Draper Laboratory, immediately following the symposium.

PROJECT PROCEED

In collaboration with the Department of Chemical Engineering and under the sponsorship of the National Science Foundation, C. A. E. S. participates in a program to develop modular aids to continuing engineering education. The project directors are: Professors Lawrence B. Evans and Karen C. Cohen of the Department of Chemical Engineering and Professor Tribus of C. A. E. S. The project is planned to run three years and is expected to accomplish three things: to demonstrate the feasibility of a modular approach to continuing education which permits the user to combine elements of instruction according to his or her needs; to demonstrate the viability of a delivery system; and to demonstrate the viability of a support system, including credentialing.

Modules in the field of industrial energy conservation are now being produced. The system design is being developed.

TECHNICAL CURRICULUM RESEARCH AND DEVELOPMENT PROJECT

C.A.E.S. provides administrative support and office space for the Technical Curriculum Research and Development Project, supervised by Professor Merton C. Flemings of the Department of Materials Science and Engineering. This objective of the project, sponsored by the Imperial Organization for Social Services (IOSS) of the Government of Iran, is to develop curricula and innovative course materials for the Shiraz Technical Institute, a new two-year technical college being established in Shiraz, Iran. The college is being designed in collaboration with Wentworth Institute, and is designated as a "Lighthouse" institution of engineering technology education, serving as a model for Iran's rapidly developing technical education system. Project activities are directed by Dr. John McWane, with a staff consisting of Dr. Richard Duffy (Research Associate), Barry Levine (graphics), and Peter Weyman (composition and secretarial support). Current projects include development of new introductory courses in electronics and instrumentation and in mechanical systems, slide-tape learning modules in mathematics, videotaped learning units in electronics, a course in industrial management, and the design of a solar-energy learning laboratory. Professor Tribus serves on the joint IOSS-M.I.T. Advisory Board for the project.

OTHER ACTIVITIES

At the urging of the President and the Dean of Engineering, the Center has proposed to the Engineering and Academic councils a conference program that would offer, to mid-career professionals, seminars and short courses. It is anticipated that these programs will be held both on and off campus. The proposal is in its final review. These programs will be instituted in the next academic year.

The activities of C.A.E.S. are reviewed periodically by an Academic Advisory Committee consisting of: Professors Frank E. Perkins (Chairman) Head of the Department of Civil Engineering; Fernando J. Corbato, Associate Head of the Department of Electrical Engineering and Computer Science; Ernest G. Cravalho, Associate Dean of the School of Engineering; Norman Jones of the Department of Ocean Engineering; Amedeo R. Odoni of the Department of Aeronautics and Astronautics; and J. Francis Reintjes of the Department of Electrical Engineering and Computer Science. The committee is appointed by Dean Alfred A.H. Keil and reports to him at least annually.

MYRON TRIBUS

Center for Policy Alternatives

The Center for Policy Alternatives is chartered to study and investigate substantive issues facing society, particularly those in which technology and engineering could play significant roles. The Center's basic purpose is to foster informed decision making for public and private policy by increasing our knowledge of the nature of the complex and interrelated problems of technological societies and by contributing to the practical understanding of effective policy formulation and evaluation. Among the Center's primary functions are the identification of major sociotechnical issues facing society, the assessment of the consequences of present policies and practices, and the development and appraisal of alternative actions for government, industry, labor, and education which will respond effectively to society's needs. In carrying out its sponsored and ongoing research programs, the Center serves as a focal point for some of the policy oriented activities of M.I.T. departments, centers, and laboratories, and seeks to stimulate faculty and students to participate in projects which have the greatest potential for social and economic utility.

Established in 1972, the Center's development has been characterized by increasing interaction with educational programs of the School of Engineering and by increasing contact with decision processes on technology policy at the national level. These trends continued during fiscal year 1977 as the Center's sponsored funding base broadened and as staff participation in formal instructional programs became more established.

RESEARCH

The Center's sponsored research volume in fiscal year 1977 was \$1.3 million, up from \$1.1 million in fiscal year 1976. The Center's sponsored and developmental research activities during the fiscal year can be summarized in seven program areas: technology policy and innovation; manpower policy; consumer policy; industrial productivity policy; environmental and workplace regulation; natural resources and energy; and communications.

Technology Policy and Innovation

The Technology Policy and Innovation Program included seven sponsored projects and several developmental research activities. One aspect of this program is concerned with the influence of national policies on innovation and technical change within various industries and national settings and with the formulation of alternative policies for the US and foreign environments. The second, and complementary research interest, focuses on understanding the processes of innovation and technical change within the firm, and the private practices and public policies that influence these processes at the level of the firm.

In February the Center was invited by the Organization for Economic Cooperation and Development (OECD) to summarize the Center's general findings on technology, public policy, and innovation at the OECD conference on Government Measures and Mechanisms for the Stimulation of Industrial Innovation and Technological Change. Dr. J. Herbert Hollomon, Director of the Center and Japan Steel Industry Professor of Engineering. Dr. Nicholas A. Ashford, Senior Research Associate, and Research Associates Dr. Marvin A. Sirbu and

Dr. James M. Utterback presented the Center's research findings at the conference and to the Advisory Committee of the OECD Science and Technology Directorate.

Research continued on the Center's 14-month project sponsored by the Delegation a l'Amenagement du Territoire et a l'Action Regionale (DATAR), an agency of the French government responsible for national programs of regional development. The project's first phase focused on identifying and examining the conditions under which successful, self-sustaining implementation of technology oriented complexes in regions can and do take place. The Center's findings were presented at a DATAR conference on technology and regional development in Nice during spring, 1977. The second phase of research is scheduled for completion in fall, 1977 and is concerned with the special problems of traditional industries in acquiring and implementing new technologies. The research team consists of Professor Hollomon, Dr. Sirbu, Robert Treitel, Research Staff, and Professor Edward B. Roberts of the Sloan School of Management.

Last summer, under a grant from the National Academy of Engineering (NAE), the Center prepared a fact book on the relationship between technology and international trade. The document summarized the legal arrangements affecting international trade as well as trade statistics, and was presented at a national NAE workshop attended by decision makers from government, industry, labor, and education. Participants included Professor Hollomon, Research Associate George Heaton, and several graduate students.

The Center's 18-month research project examining the economic impact of the National Sea Grant Program on US industry and foreign trade was completed at mid-year. Funded by the National Oceanic and Atmospheric Administration (NOAA), the Center's analysis was based on a detailed study of a sample of projects with apparent commercial promise and of firms in related industrial sectors. The transfer of this project's findings and evaluative techniques to the Office of Sea Grant is being carried out with additional NOAA support. Participants during the year included Professor Hollomon and Dr. Utterback; Byron F. Battle, Dr. Linsu Kim, and Dr. Albert E. Murray, Research Associates; Dr. Blair M. McGugan, Visiting Research Associate on leave from the Ministry of State for Science and Technology in the Canadian government; Dr. James B. Webber, Visiting Research Associate; and several graduate students.

Under a National Science Foundation (NSF) grant, Drs. Utterback and Kim and a graduate student began an examination of the relationship between evolving product and process technology. Directed by Dr. Utterback, this research seeks to develop a conceptual framework and a consistent set of hypotheses that account for the dynamics of firms' processes of innovation. The work draws upon the findings and results of a large number of descriptive studies and information that to date have provided diverse and fragmented views of the innovation process. The intent of this present research is to integrate, synthesize, and extend existing knowledge into a framework that has utility for managerial and government decision makers.

During the year, Drs. Utterback and Murray conducted a study of the influence of Department of Defense sponsorship of electronics research, development and procurement on the development of the US civilian electronics industry. The research was undertaken for the Experimental Technology Incentives Program (ETIP) in the Department of Commerce, and considered direct and indirect procurement, research and development funding, and support for initial process development as well as indirect support through fellowships, training grants, and sponsored research in universities. The analysis focused on the impact of these practices on technology and technical improvements within the industry, the economics and structure of the industry, and the quality and mobility of manpower resources within the industry.

During fall and winter, 1976, a number of the Center's staff were engaged in preparing a resource document that identified key issues for government actions affecting technological

innovation in the civilian US economy. Prepared for the Office of Technology Assessment's Panel on the Applications of Science and Technology, the document included a series of explicit policy issues concerning how government action could materially influence the speed, direction, and character of innovation and thereby the use of science and technology in the US civil sector. Participants included Drs. Hollomon, McGugan, Kim, K. Nagaraja Rao, Senior Research Associate, Joel Schechter, Visiting Research Associate on leave from the Research and Development Institute of Ben Gurion University in Israel, Mr. Heaton, and a graduate student.

At mid-year, Drs. Hollomon and James Katz, an NSF Postdoctoral Fellow, undertook an examination of the feasibility of a major federal extension service program to provide technical and managerial information to business and industry, particularly medium and small-sized firms. A preliminary document identifying several legislative options has been prepared and the study is scheduled for completion in fall, 1977.

Manpower Policy

The influence of public policy and private practice on the supply, demand, and training of professional and technical manpower is a long-standing Center research interest. As a part of the School of Engineering, the Center's first concern has been the engineering profession and much of the Center's early manpower research focused on developing econometric models for forecasting the market for engineering graduates. These models relate demographic, enrollment, salary, market demand, and government support for education to the supply of young people opting for certain professions. Recent research efforts have applied these models to additional professions in the US and in foreign countries. A second dimension of the Center's ongoing manpower research activities is concerned with the more general problem of the impact of changing college enrollments on institutions of higher education, particularly as they influence present education configurations and the attractiveness of alternative educational delivery systems.

The Center's two and a half-year Venezuela manpower project is in its final phase and is scheduled for completion in late summer, 1977. The program is being funded by the Fundacion Gran Mariscal Ayacucho (FGMA) scholarship program, the largest scholarship program in Venezuela. Under the direction of Dr. Rao, the research effort has analyzed supply and demand phenomena in Venezuela for engineers, managers, school teachers, and technicians in order to provide policy guidance for the FGMA scholarship program. The project involved structured interviews with more than 170 public and private enterprises in several economic sectors and the application of dynamic manpower adjustment models. An important aspect of the overall program is the training of Venezuelan professionals in the new methodologies and techniques of manpower forecasting. Dr. Rao's research team during the past year included Professor Richard B. Freeman of Harvard University; Orlando Lopez-Lovera, Research Staff, who served as a project manager; Dr. Kim; Mr. Treitel; Arnoldo Gutierrez, Jose Mayora and Stella Pinto, on leave from the government of Venezuela; and Jurgen Hausler, a student intern from the University of Konstanz, West Germany.

Throughout the year Dr. Rao participated in the Joint M. I. T. /Wentworth Institute program assisting the Imperial Organization for Social Services (IOSS) of the State of Iran in establishing the Shiraz Technical Institute. Dr. Rao served on the joint M. I. T. /IOSS advisory board for the new institute and conducted a community analysis to determine the educational resources in the Fars region and the technical manpower needs in several Iranian industrial sectors.

In October, a Center research team under the direction of Dr. Sirbu began a two-year project to extend and refine existing econometric models used for forecasting the supply and demand for graduates in science and engineering in the US. In addition to extending current models

to more disciplines and developing improved indices of demand, particular attention is being given to the relative demand for scientists and engineers compared with other occupations. A further aspect of the program is the development of econometric models that encompass the total stock of scientists and engineers and thus take into account attrition and inter-industry mobility. The research program is being funded by NSF and involved Professor Freeman of Harvard University, Mr. Treitel, Mr. Jonathan Leonard, Research Staff, and several graduate students.

Consumer Policy

The Center's Consumer Policy Program is broadly concerned with government policies affecting consumer health and welfare and with consumer behavior patterns, particularly the economics of consumer choice, including elements of life-cycle costs, product life, and consumer protection. A major activity of this program is the warranties, service contracts, and alternatives project which is being funded by NSF and directed by Senior Research Associate Robert T. Lund. This three-year program is examining the warranty and service contract system for consumer appliances, including its legal context, the pattern of consumer behavior, and the economic and social consequences of various alternatives to the present system. Funded by NSF, the project is scheduled for completion in late 1977. One outcome of this research is the identification of the possibility of extending the use of life-cycle costing, until now primarily a research tool, to the general consumer public as a decision-making tool. Participants during the year included Mr. Heaton; Dr. Stewart A. Butler, Research Associate; Judith I. Katz, Research Staff; Professor Warren H. Hausman of the University of Rochester; Professor Leon Courville of École des Hautes Études Commerciales in Montreal; Professor Warren G. Briggs of Bentley College; Professors Keith Bryant and Jennifer Gerner of Cornell; a Charles Stark Draper Laboratory research team; and several graduate students.

At year end, the Center received a grant from NSF to conduct a two-day national conference on consumer research for consumer policy. The conference will address the policy implications of recent consumer research and will develop ideas and recommendations for improving the ways in which research can contribute to the formulation of consumer related policy. Chaired by Mr. Lund, the conference will include over 70 invited attendees from government, industry, education, and consumer related interest groups, and represents one of the first attempts to bring together consumer advocates, consumer researchers, and private and public decision makers at a national conference on consumer research issues. Dr. W. Michael Denney, Visiting Research Associate, is a key Center participant.

A developmental activity examining licensure for various professions and occupations continued under the direction of Mr. Lund. A research plan has been developed for a major program that would examine the effects of occupational licensure in selected professions on the consumer on a national basis, and then formulate corrective actions for the benefit of consumers. Initiatives for funding the first phase of research, which would involve the Massachusetts Office for Consumer Affairs, are under way.

Industrial Productivity Policy

The Center's Industrial Productivity Policy activities are concerned with identifying new opportunities for technology in industry and with the relationships among productive processes, technology, job design, and social goals. Mr. Lund continued his participation in the joint M.I.T.-Industry Polymer Processing Program directed by Professor Nam P. Suh of the Department of Mechanical Engineering. During the coming year, this NSF supported experimental program will be in its fifth and final year, and Mr. Lund will be preparing the project evaluation report. Mr. Lund is also participating in a new Air Force program examining

Integrated Computer Aided Manufacturing (ICAM) technology. Through a subcontract from Softech, Inc. of Waltham, Mr. Lund is conducting a preliminary appraisal of the scope of possible ICAM technology impacts on the structure of industry, manufacturing strategy, employment, the nature and organization of work, as well as the physical environment. This modest effort is presently defining a larger research initiative that would examine potential ICAM impacts in more detail as an integral part of the overall Air Force program.

Following a preliminary examination of the opportunities for improving the cost and delivery of housing in Israel, the Center began in summer, 1976 a four and a half-year research program on innovation in housing production in Israel. Directed by Professor Robert D. Logcher of the Department of Civil Engineering, the program is being funded by the Jewish Agency for Israel for the Israeli Ministry of Housing and involves a participating research group at the Institute for Technology at Haifa (Technion). The program is intended to lead to a demonstration housing program in Israel and includes market tests of alternative housing forms and production processes. Participants during the year included Professor Emeritus Albert G. Dietz of the Department of Architecture, and Professors Raymond E. Levitt and William A. Litle, Research Associate Henry Irwig, and several graduate students from the Department of Civil Engineering.

Workplace and Environmental Regulation

Center research activities concerned with workplace and environmental regulation continued to expand and broaden throughout the year. These activities generally involve identification of alternative strategies for regulation and evaluation of regulatory impacts by a variety of techniques. They are concerned with the effects of regulation on worker and community health and safety and on the connection with the manufacturing process. The continuing development of analytical and methodological techniques for the complex technical, economic, political, and legal issues involved is an integral part of all of the Center's efforts in this area.

Dr. Joel C. Clark of the Department of Materials Science and Engineering is directing a major program examining the multiple impacts of Federal, state, and local regulations on the copper wire industry. The development of a methodology for assessing the costs and benefits of all levels of regulatory involvement, ranging from tax depletion allowances to air pollution control, is a central aspect of this NSF funded project. An important dimension of this program is the participation of representatives from industry, state and local governments, labor, and public interest groups with the Center's 10-member research team and graduate students.

Dr. Ashford is directing a 16-month program examining the relationships between environmental/safety regulation and technological responses and innovation under an NSF grant. The program is examining selected production segments in the chemical and allied product industries and involves Mr. Heaton and Ms. Katz; Dr. Dale B. Hattis, Research Associate; Professor Lawrence B. Evans of the Department of Chemical Engineering; and several graduate students.

Research activities for the Occupational Safety and Health Administration (OSHA) of the Department of Labor and for the Environmental Protection Agency (EPA) continued under the direction of Dr. Ashford. The OSHA research focused on the classification of occupational health hazards and possible OSHA strategies for securing hazard abatement. The work is being carried out in collaboration with ICF, Inc. of Washington, DC, and involves Dr. Hattis, Mr. Heaton, Ms. Katz, and Sally T. Gorski, Research Staff. The EPA research continues to focus on alternative strategies and regulatory options for controlling workplace noise and involved Eric Zolt, Research Staff, in addition to Dr. Hattis, Mr. Heaton, and Ms. Katz.

As the year came to a close, funding was received from ETIP for an initial feasibility study of two experimental programs that could enhance OSHA's ability to better achieve its regulatory missions. These programs are the establishment of experimental health maintenance organizations and the establishment of joint labor/management safety and health committees. The study is being carried out by Dr. Hattis and Ms. Gorski, and is expected to lead to initiatives for funding in the coming year. An examination of regulation and innovation in the pharmaceutical industry was conducted by Drs. Ashford and Butler and Mr. Zolt, and has led to initiatives for a major funded program.

Natural Resources and Energy

In fall, 1976 the Center's eight-month project for the National Commission on Supplies and Shortages was completed. The study addressed proposed government actions and alternative institutional arrangements for ameliorating present and future shortages, disruptions, and oversupplies of resources and commodities in the US. The research group included Professor Clark of M. I. T., Professor Gordon A. Christenson of American University, Professor Walter Hibbard of Virginia Polytechnic Institute and State University, Professor John Tiltin of Pennsylvania State University, and Professor Marc Tipermas of the State University of New York at Buffalo in addition to Center staff and graduate students.

In October the Center conducted a workshop for the Energy Research and Development Administration that examined strategic alternatives for energy conservation in the US. The attention of the workshop was focused on the energy system as a whole rather than at the level of specific technologies, and conservation options were discussed in terms of their potential impact on product and process change, the timing of change, and consumer responses. Participants included Dr. Hollomon, Dr. Utterback, Dr. Sirbu, Professor Harvey Sapolsky of the Department of Political Science, and Professor Daniel Rich of the University of Delaware.

At mid-year the Center's study of the potential industrial applications of chitin and chitin derivatives was completed. Funded by the M. I. T. Sea Grant program, this research focused on identifying business as well as technical uncertainties whose resolution will be important if chitin is to be developed as a viable commercial product. The study involved Drs. Ashford, Hattis, and Murray, and research findings were presented at the First International Conference on Chitin/Chitosan in spring, 1977.

Mr. Lund's continuing research on improving product life as a strategy for conserving material resources was outlined in a Technology Review article in January. The article identified several issues requiring research and increased understanding before effective policies for promoting longer product life can be developed and appraised. At mid-year, a modest program funded by EPA was undertaken to develop case study materials aimed at increasing the participation of local government officials and private citizens in areawide water planning processes. The work is being carried out by Dr. Ashford, Ms. Gorski, and Marc O'Brien, a graduate student in the Department of Political Science.

Communications

During the latter half of the year, Dr. Sirbu began an examination of policy issues and the development of research approaches for two potential communications programs. One effort focuses on the impacts arising from the adoption of recent technologies, such as word-processing systems and mini-computers, within the office environment. The program would assess the potential impacts of office automation on traditional employment patterns, the nature of office work and organizational structure, as well as the effects on industries producing office equipment and international trade. The second developmental activity is concerned

with the effect of regulatory policy on the rate of innovation in telecommunications services, particularly with respect to the apparently different regulatory attitudes and innovation rates within the data processing industry and the telecommunication industry. Both of these activities are in a formative stage at year end, and initiatives for research funding will be made during the coming year.

EDUCATIONAL ACTIVITIES

The active participation of undergraduate and graduate students with Center staff in sponsored and developmental research projects is one dimension of the Center's role in the education and training of engineers and students in the School and the Institute. The Center staff also contribute to the development of new degree programs, design and teach new subjects, and serve as advisors to students.

Following the development of a new Master's degree program for engineers, Dr. Sirbu joined Professor Thomas B. Sheridan of the Department of Mechanical Engineering and Dr. David Noble, Research Associate in the School of Humanities and Social Science, in presenting the Proseminar in Technology and Policy to the first class of students in the new Technology and Policy Program. The program, leading to a Master's degree in Technology and Policy, is an intensive graduate program for students who wish to study economics, social science, and systems analysis at the same time that they are taking a concentration of subjects in one of the engineering disciplines. The case study materials used in the proseminar had been developed by Dr. Sirbu, Professor Sheridan, and Dr. Noble during 1975-76.

Mr. Lund, also Lecturer in the Department of Mechanical Engineering, and Professor David P. Hoult of the Department of Mechanical Engineering again taught 2.96J Management in Engineering, a joint offering of that department and the Department of Electrical Engineering and Computer Science. The objectives, teaching method, and curriculum of this recently developed subject were summarized by Mr. Lund and Professor Hoult at the annual meeting of the American Society for Engineering Education in June 1977. Mr. Lund again taught 2.863 Elements of Manufacturing during fall term. Dr. Ashford, assisted by Ms. Katz, taught 16.793 The Law/Technology Interface during spring term as part of the Institute's Law-Related Studies program. As Adjunct Professor of Law at the Franklin Pierce Law Center, Dr. Ashford continued his elective seminar on Law, technology, and the work environment.

Two new subjects were developed by Center staff during the year. Dr. Utterback developed and taught a subject addressing innovation and technological development, 2.995 Special Topics in Mechanical Engineering, on a trial basis during fall term. Also offered as 15.795 Seminar in Operations Management, this subject will be offered as 2.95 Innovation and Industrial Development during the coming year and will be taught by Dr. Utterback and Professor Sheridan. During spring term, Dr. Ashford with the assistance of Ms. Gorski developed 10.805J Technology, Law and the Working Environment, a new graduate-level subject scheduled to be offered in fall, 1977. This will be a joint offering of the Department of Chemical Engineering and the Department of Materials Science and Engineering and will involve Professors Clark and Evans.

J. HERBERT HOLLOMON

Center for Transportation Studies (C.T.S.)

The year has been one of consolidation for the Center and improvement in the services offered. The research volume handled through the Center has remained at a high level. Course offerings in transportation have been at an all-time high and both regular academic programs and special program offerings have increased. The financial base of the Center has improved with the addition of an allocation account on those research contracts administered through the Center.

The makeup of the Steering Committee has remained as last year. It consists of: Professor Alan Altshuler, Department of Political Science and Department of Urban Studies and Planning; Professor Ernst G. Frankel, Department of Ocean Engineering; Professor Ralph G. Gakenheimer, Department of Urban Studies and Planning, representing the School of Architecture and Planning; Professor Peter L'Orange, Sloan School of Management; Professor Paul O. Roberts, Department of Civil Engineering; Professor Herbert H. Richardson, Department of Mechanical Engineering; Professor Joseph M. Sussman, Department of Civil Engineering and Head of the Transportation Systems Division; Professor Robert W. Simpson, Department of Aeronautics and Astronautics and Director of the Flight Transportation Laboratory; Professor William C. Wheaton, Department of Economics and Department of Urban Studies and Planning, representing the School of Humanities and Social Science.

Professor Paul O. Roberts has continued to act as the Director of the Center.

The Center continues its relationship with Dr. Daryl Wyckoff of the Harvard Business School and Dr. Frank C. Colcord, Jr. of Tufts University, both of whom have appointments as Research Affiliates.

The administrative staff of the Center includes: Louise Carella, Administrative Assistant; Janice Christie, Secretary; Rebecca Lacy, Publications; and Barbara Bachtell, Secretary (part-time). Research staff includes: Elizabeth Deakin, Research Associate; Marc N. Terziev, Research Engineer; Thomas B. Brigham, Research Engineer; Ann Rappaport, Research Engineer; Carol A. Miller, System Analyst. The Center in the past year has had research projects involving some 12 professors from various departments throughout the Institute.

Graduate students from several departments hold research assistantships on research contracts funded through the Center. Additional undergraduate and graduate students are employed on the hourly payroll and through the UROP office.

The Center's offices are located in Building 5, Rooms 204 and 206. Additional research and publications facilities are located in Rooms 5-008 and 5-014. The Transportation Information Center has been located this last year in Room 1-163.

PROGRAMS OF THE CENTER

Newsletter

The newsletter has been published for summer, 1976, fall, 1976, and spring, 1977. It continues to report recent contracts, seminars and workshops and other transportation related news which takes place at the Institute. Rebecca Lacy has served as the editor of the newsletter.

Transportation Information Center

The Center has continued to support the Transportation Information Center. Rebecca Lacy is responsible for the coordination and operation of this facility. Copies of all available M.I.T. transportation related publications, as well as copies of frequently referenced texts and current publications and magazines, are contained in the Transportation Information Center.

Transportation Research Reports

Published reports in the C.T.S. Report Series for 1976-77 number 25. They are:

<u>C.T.S. Report Number</u>	<u>Title and Author(s)</u>
76-8	"Representing Industry and Population Structure for Estimating Freight Flows," Yu-Sheng Chiang, Paul O. Roberts, August 1976;
76-9	"Analysis of Freight Markets," Paul O. Roberts, Henry S. Marcus, Roger A. Longhorn, August 1976;
76-10	"User Manual: The Logistics Strategy Analyzer," Roger A. Longhorn, August 1976;
76-11	"A Bibliography of Network Models in Transportation," Robert W. Simpson, Peter Kivestu, August 1976;
76-12	"An Integrated Policy Model for the Surface Freight Transportation Industries," Studies in the Economics of Federal Transportation Policies, Number 1, Ann F. Friedlaender, September 1976;
76-13	"Econometric Estimation of Cost Functions in the Transportation Industries," Studies in the Economics of Federal Transportation Policies, Number 2, Richard Spady, Ann F. Friedlaender, September 1976;

<u>C. T. S. Report Number</u>	<u>Title and Author(s)</u>
76-14	"Analysis of the Incremental Costs and Trade-offs Between Energy Efficiency and Physical Distribution Effectiveness in Intercity Freight Markets," (FEA Final Report), Paul O. Roberts, Marc N. Terziev, James T. Kneafsey, Lawrence B. Wilson, Ralph D. Samuelson, Yu-Sheng Chiang, Christopher V. Deephouse, November 1976;
76-15	"Information Needs and Performance Measures," Studies in the Economics of Federal Transportation Policies, Number 3, Richard de Neufville, Clifford King, September 1976;
76-16	"Models of Travel Time and Reliability for Freight Transport," Marc N. Terziev, Paul O. Roberts, December 1976;
76-18	"User Manual for Freight Transportation Analysis Software," Marc N. Terziev, Lawrence B. Wilson, December 1976;
76-19	"Optimization of Elevator System Configuration," Yosef Sheffi, December 1976;
76-20	"Rochester Integrated Adaptable Metropolitan Transit Service Program First Year Report," Submitted to: Urban Mass. Trans. Admin., Rochester-Genesee Regional Transportation Authority, June 1976;
77-1	"Some Aspects of Regulatory Reform of the US Trucking Industry," Paul O. Roberts, January 1977;
77-2	"A Comparison of Freight Transportation Carrier Costs and Rates Charged," Ralph D. Samuelson, February 1977;
77-3	"A Methodology for Estimating Detailed Interarea Commodity Freight Flows from Census of Transportation Data," Christopher V. Deephouse, Yu-Sheng Chiang, Paul O. Roberts, Ralph D. Samuelson, February 1977;
77-4	"The Rationale and Scope of Federal Transportation Policy," Studies in the Economics of Transportation Policies, Number 4, Ann F. Friedlaender, Robert W. Simpson, Ernst G. Frankel, Richard de Neufville, James Sloss, March 1977;
77-5	"Hedonic Costs and Economies of Scale in the Regulated Trucking Industry," Studies in the Economics of Transportation Policies, Number 5, Ann F. Friedlaender, January 1977;
77-6	"Forecasting Freight Demand," Paul O. Roberts, April 1977;
77-7	"Modeling the Freight Rate Structure," Ralph D. Samuelson, February 1977;

<u>C. T. S. Report Number</u>	<u>Title and Author(s)</u>
77-8	"Advanced Airline Planning Models -- A Tool for Developing Regulatory Policy," R. W. Simpson;
77-9	"TOFC Shuttle Trains: A Study in Equilibrium Analysis," Ralph D. Samuelson, Paul O. Roberts, June 1977;
77-10	"COFC vs. TOFC: A Comparison of Technologies," Ralph D. Samuelson, Paul O. Roberts, June 1977;
77-11	"Development of a Policy Sensitive Model for Forecasting Freight Demand," Paul O. Roberts, Moshe Ben-Akiva, Marc N. Terziev, Yu-Sheng Chiang, April 1977;
77-12	"Policy Analysis and Forecasting Models for US Domestic Air Cargo Movements." Lawrence B. Wilson, July 1977.

Other transportation related research reports are published by the various laboratories and departments associated with the Center.

Transportation Related Publications List

A publications list has been prepared for distribution containing all significant transportation related reports developed by the faculty and staff at M. I. T. since the year 1960. Copies of the list and the publications therein can be ordered from Rebecca Lacy in the Transportation Information Center.

Luncheon/Seminar Series

The Luncheon/Seminar Series was continued throughout this past year by the Center. The format was buffet luncheon followed by an informal talk by an invited speaker on some timely policy issue. Some 20 speakers participated in the series over the fall and spring terms including:

Frederick W. Smith, Chairman of the Board, Federal Express Corporation, "Appearances Are Sometimes Deceiving."

David Hewes, Vice President of the Boston & Maine Railroad, "Work Rules: Reality or Myth?"

Robert R. Kiley, Chairman and Chief Executive Officer at the Massachusetts Bay Transit Authority, "MBTA -- Where Is It Going."

Charles F. Butler, President, Air New England, "The New Air New England."

John Wild, Executive Director of the National Transportation Policy Study Commission, "Whither US National Transportation Policy?"

Dr. Paul H. Banner, Executive Vice President of Rock Island Railroad,
"Will the 4R Act Work?"

Otto A. Becker, Senior Vice President-Field Sales and Services,
American Airlines, Inc., "How to Manage an Airline for Fun and Profit."

Research Programs

During the year, 20 proposals were submitted under the auspices of the Center for Transportation Studies. Of these, 12 were successful (five of which were extensions to various projects and two were add-ons to one specific project). These new projects, new extensions, add-ons and other continuing projects have an approximate value of \$1 million for the next fiscal year. Research projects included:

<u>Title</u>	<u>Sponsor</u>	<u>Supervisor</u>
Analysis of the Incremental Cost and Trade-Offs between Energy Efficiency and Physical Distribution Effectiveness in Intercity Freight Markets	Federal Energy Administration (FEA)	P. Roberts
Improving TOFC/COFC Performance with Shuttle Trains	Federal Railroad Administration/FEA	P. Roberts
Analysis of Freight Markets	US Dept. of Transportation (DOT)/Univ. Res. Prog.	P. Roberts H. Marcus
Freight System Evaluation	DOT/FEA	P. Roberts
New Perspectives in Urban Transportation: Strategies for Overcoming Barriers to Innovation	DOT/Univ. Res. Prog.	A. Altshuler
Transportation Network Analysis and Decomposition Techniques	DOT/Transportation System Center	R. Simpson
Evaluation Framework for Transportation Planning in Developing Countries	Dept. of State AID	F. Moavenzadeh
Improve the Integration of Air Quality Considerations into Transportation Decision Making	Environmental Protection Agency	M. Manheim
Reaching Power Plant Siting Decisions with Environmental and Social Consequences	NSF	M. Manheim
Scenarios for Alternative Roles of the Federal Government in Transportation	DOT/Univ. Res. Prog.	A. Friedlaender

<u>Title</u>	<u>Sponsor</u>	<u>Supervisor</u>
Development of an Aggregate Model of Urbanized Area Travel Behavior	DOT	P. Roberts
Offshore Liquefied Natural Gas Terminals	DOT/Univ. Res. Prog.	H. Marcus
The Impact of Regulation Upon Technical Change in the RR Industry	NSF/Office of R&D Assessment	A. Freidlaender
Railroad Reliability and Car Utilization	Assoc. of Amer. Railroads	J. Sussman
Urban Transportation Policy Studies	Urban Mass Transit Administration	D. Roos R. Gakenheimer
A Study in Policy Sensitive Freight Model Development	DOT/Office of the Secretary of Transportation	P. Roberts
Research to Develop Methods for Evaluating TSM Alternatives	DOT/TSC	M. Manheim

M.I.T. Press Series on Transportation: The agreement signed between the M.I.T. Press and the Center for Transportation Studies will allow the Press to publish a series of books and monographs dealing with transportation topics. The Center for Transportation Studies' Steering Committee acts as the editorial board for the series and the series editor. The editorial board will make recommendations to M.I.T. Press regarding books in the series and will suggest potential authors and solicit manuscripts to promote it.

Student Poster "Transportation Educational and Research Opportunities": A one-page brochure with detachable card returnable to the Center for Transportation Studies for information regarding transportation opportunities at M.I.T. was sent this year to universities throughout the United States and several foreign countries. The applications from US citizens approximately doubled, largely, we feel, as a result of this effort. A similar effort is contemplated for the coming year.

Transportation Summer Program: A coordinated set of six mini-courses on transportation is being offered to practicing professionals for the first time in summer, 1977. These courses, which last for one to two weeks, have been designed to interface with one another. It is possible to register for a subject in a single specialty area or to mix the contents of the various subject offerings to achieve the special needs of an individual student. The course offerings, made through the M.I.T. Summer Session Office in conjunction with the Center, include Transportation Systems Management, Air Transportation, Port Planning and Development, Urban Transportation Issues and Techniques, Freight Transportation, and Forecasting Transportation Demand.

Transportation Executive Symposia: Several executive-level transportation symposia of one to five days' duration have been planned and carried out over the last few years. This year the Center, in conjunction with the Industrial Liason Office, offered a one-week course in

Innovation Center

Zurich on "Transportation Issues: Techniques for Analysis and Planning." The success of the program suggests that it should be repeated elsewhere.

PAUL O. ROBERTS

Innovation Center

The Innovation Center, established at M.I.T. for the purpose of developing an educational program for future industrial leaders by emphasizing the process of inventions and entrepreneurship, has completed its fourth year as a National Science Foundation (NSF) funded experiment. The original agreement for a five-year program is to be completed in just about one year. Jointly with members of the Institute and School of Engineering administrations, the Center has begun to prepare for an in-depth evaluation of the program and for future operation and funding after the NSF agreement terminates.

Operationally, the Innovation Center may be described in terms of three activities: the Innovation Education Program which concentrates on classroom and laboratory teaching; the Innovation Co-op which concentrates on providing "hands-on" experience in innovation through the development and commercialization of various marketable products; and the Center's research on the invention process which focuses on methods for teaching invention and the evaluation of inventions.

The Innovation Education Program (I.E.P.)

Under the auspices of the Center's Innovation Education Council (I.E.C.) four classes were offered during each term this past year; in addition, an undergraduate seminar was offered in the fall. Class enrollment remained stable with 148 participating students.

Last year the Center offered its first Special Summer Session subject, "Innovation Workshop for Industry." The subject has been modified and will be offered this summer as "Innovation in Industry from Need to Marketplace."

In addition, the I.E.P. offered a series of "New Technology Seminars" during the 1977 Independent Activities Period. These well-attended presentations dealt with such topics as lasers, new chip technology, solar energy, and polymers. The experience accumulated over four years' involvement in teaching invention and entrepreneurship will be communicated to the academic and funding communities through the publication of a series of three books on technological innovation. Members of I.E.C. will serve as coauthors.

While considerable results have been achieved, the Center will continue to evaluate and modify its teaching program in order to increase its effectiveness. Because of its interdepartmental nature, it is felt that the teaching program should continue as a unit in the School of Engineering. To this end, approval has been obtained from the Provost to raise \$1 million in expendable funds within the M.I.T. Leadership Campaign to support this educational program.

The Innovation Co-op

Over the past four years two student-formed companies -- Computer Controls in the HVAC control systems business, and ECON, a company manufacturing thermalite window insulation -- have resulted from Co-op projects. In addition, six inventions covered by seven patents were developed in the Co-op and have been licensed to outside companies. These include: TV Tennis, TV Hockey/Soccer, Television Interface Device, Blood Gas Detector, Herpes Simplex Inactivation, and Precious Metals Forgery Detection System. Three of these seven were developed under contract with the Company that licensed the resulting inventions. Two other product development contracts were obtained with outside companies during the past year. Other such contracts are under negotiation. Of particular interest is the Three Dimensional Graphic Display Device. The Co-op is currently negotiating an 18-month, \$148,000 contract with an outside company to develop this invention which was submitted by a freshman enrolled in the Center's undergraduate seminar during fall, 1975.

In view of the impending termination of the Center's NSF funding, the Co-op is reviewing its operating procedures and structure with the goal of achieving financial self-sufficiency by fall, 1978. Of particular concern is the implementation of an appropriate and effective incentives plan, without which innovation cannot be stimulated. In this vein, the possibility of setting up the Co-op at arms' length from the Institute is presently under study as are methods for generating increased student and faculty participation in the Co-op projects.

The NBS Supported Program

Parameter analysis, a methodology for making and evaluating inventions, is being developed under contract (\$95,000 for 15 months) with the Office of Energy-Related Inventions (OERI) of the National Bureau of Standards (NBS). The goal of the project is to refine this methodology as applied to the evaluation of energy related inventions in order to assist OERI in its task and, eventually, to benefit the entire invention community.

Under the contract, Center faculty and staff have evaluated 25 inventions supplied by OERI. Two new inventions have resulted as by-products of this evaluation process. The "Thermal Engine with Entrapped Working Medium" has been assigned to M.I.T. A patent application has been filed and the invention has been submitted to OERI to be processed through existing invention evaluation channels. The invention has passed the "first stage" and is undergoing "second stage evaluation." The second invention involves a significantly more energy-efficient method for drying clothes or commodities.

The project team plans to submit a proposal to NBS this summer for a more extensive long-term project (\$250,000 each year for four to five years).

Y. T. LI

Electric Power Systems Engineering Laboratory

The Electric Power Systems Engineering Laboratory (E. P. S. E. L.) of the School of Engineering is engaged in a wide range of educational and research activities relating to the generation, transmission, processing, and utilization of electrical energy. Personnel in the laboratory supervise both undergraduate and graduate theses encompassing a wide range of disciplines within the field of electric power systems engineering.

Electric Power Systems Engineering Laboratory

A brief description of the activities in E. P. S. E. L. will illustrate the diversity and scope of its research. A highly accurate physical scaled power system model consisting of generators, transformers, circuit breakers, and transmission lines is being used to evaluate power system dynamic performance. A major project to develop control strategies and techniques to maximize power systems integrity under emergency conditions was begun early in 1976. This project utilizes the model power system interfaced with a digital computer to test and evaluate new control strategies. The model system is also being used to evaluate the potential of permanent damage to turbogenerator shafts due to system operations such as high speed reclosing and line switching.

High power semiconductor circuits are being integrated with energy storage devices to provide highly efficient interfaces between conventional power system and novel energy generation and storage systems. Also being developed are new approaches to the simulation of energy conversion systems employing power semiconductor devices. The mechanisms of contamination and flashover on both ac and dc transmission systems are being investigated via several projects in the laboratory. Finally, a major effort is under way to extend the state of the art in superconducting generator technology. This project is aimed at meeting the needs of future electric power systems via machines of higher rating and smaller size with improved stability and terminal voltage ranges. Work also continues in load modeling with respect to energy usage and its effect on rate structures.

At the present time, eight faculty members, 23 graduate students, 12 undergraduate students, and four research members are associated with the Laboratory's programs.

GERALD LOOMIS WILSON

School of Humanities and Social Science

The academic year 1976-77 was chiefly notable for its changes in personnel. With the untimely death of Professor Hans-Lukas Teuber off the coast of the Virgin Islands, the School lost one of its most distinguished figures and its most celebrated undergraduate teacher. Professor Teuber had created the Department of Psychology as it now exists almost single-handedly since 1960. The balance of research and teaching which he favored made the Department unique in its early years and has now become something of a model for psychology departments elsewhere. The appointment of Professor Richard Held to succeed Dr. Teuber is a guarantee that the Department will continue on the lines which Dr. Teuber had pioneered, but also that it will increasingly strike out in new directions as further funding becomes available.

Two other changes in department headships also took place on July 1, 1977. Professor Morris Halle, Acting Head of the newly formed Department of Linguistics and Philosophy was succeeded by Professor Samuel J. Keyser of the University of Massachusetts at Amherst, who brings to the appointment a sparkling reputation as a scholar and administrator, as editor of the journal Linguistic Inquiry, and as a conversationalist. It is significant of the friendly relations that have been established in the new Department between linguists and philosophers that though Professor Keyser is primarily a linguist, his appointment had the unanimous support of the philosophy faculty. Taking over as a new department head at the same time as Professor Keyser will be Professor Alan Altshuler who succeeds Professor Myron Weiner as Head of the Department of Political Science. Professor Altshuler, a specialist in urban politics and transportation, has been the leading figure in developing a new public policy program under the auspices of the Department of Political Science. As the holder of joint appointments in the Schools of Architecture and Planning and Engineering, Professor Altshuler is uniquely qualified to establish new links in the public policy area between the School of Humanities and Social Science and these other two Schools. The members of the School Council have greatly enjoyed their close association with Professors Halle and Weiner and wish them a happy return to their extensive research and teaching commitments.

In the Department of Humanities there have also been personnel changes affecting the Department's administration. Professor Stephen Erdely became Director of Music on July 1, 1976, succeeding Professor John Buttrick. In the course of the academic year the new posts of Director of Modern Languages and Director of the Writing Program were authorized. Professor Margery Resnick of Yale University took over the Modern Languages program on July 1, 1977 from Professor Donald Blackmer, Associate Dean of the School who has been Acting Director during the year. A national search for a Director of the Writing Program was not completed by the end of the year. During the academic year 1976-77, David Breakstone served commendably as Acting Director of the Program in peculiarly difficult circumstances.

The problem of how best to provide for the writing needs of M. I. T. students, which has been a matter of some controversy in the Department of Humanities for several years past, became a matter of general concern in the course of the year. This was partly because of the existence of divisions as how to best teach writing among teachers of writing all over the country, and partly because of circumstances peculiar to M. I. T. As Dean I have consistently tried to foster the development of writing teaching at M. I. T. and towards this end I appointed

a committee, chaired by Professor Nathan Sivin, to look into the existing teaching of writing at M.I.T. and to make proposals for the future. The report of the Sivin committee, whose membership was drawn from both inside and outside the Institute, was finally submitted on June 17, 1976 and immediately became a source of controversy. While commending the student oriented attitudes of M.I.T.'s writing teachers, the report proposed significant broadening of the offerings and a considerable number of changes in the administrative structure. During the fall, discussions were held among interested parties as to how best to move towards a broader-gauge writing program. This led to the development of a set of administrative guidelines which I prepared with the help of Professors Sivin and Blackmer and which were discussed with the faculty of the Department of Humanities in December. A very significant feature of the proposals was a provision for the first time of instruction in science writing, which has been a good deal neglected at M.I.T., and a strengthening of the offerings in technical writing. The intention to broaden the existing offerings in writing was resisted by a small group of writing teachers who publicized their views in numerous memoranda. An account of the issues at stake was given by Dean Blackmer and me in a report published in Tech Talk on April 27, 1977. A subsequent attempt to set up yet another committee on the future of writing at M.I.T. was made at the Faculty Meeting on May 18, 1977 but was rejected in a nearly unanimous vote.

I hope that in the new year there will be less controversy now that the main outlines of future development in writing have been established. Four new assistant professors and one new lecturer have been appointed to teach in the Program for the first time in 1977-78. They include a specialist in science writing who will, I hope, establish close connections with the School of Science and especially with the Course XXV committee which has become interested in science writing. This appointment has been made possible by a generous donation from the DeWitt Wallace Fund, Inc.

By contrast with the controversy over the Writing Program, there has been very little conflict in another important area where new steps were taken during the past year. For some time, discussions have suggested the need for those whose intellectual interests lie in the area now becoming known as the cognitive studies to work closer together. Regular meetings have been held involving faculty members in linguistics, philosophy, and psychology, as well as other disciplines. Towards the end of the academic year the Alfred P. Sloan Foundation agreed to sponsor further more widespread discussion involving faculty members all over the country by means of a continuing symposium to be conducted under the sponsorship of the Department of Linguistics and Philosophy. The nature of human learning is something which has fascinated human beings since the beginning of history. It begins to look as though the present is the time to make a new effort to understand just what is involved, building particularly on the advances of the last generation. This is one of those areas in which multidisciplinary cooperation is required, and we have great hopes that at M.I.T. we can establish an ongoing center where research and teaching may fruitfully be conducted.

The School has long been interested in developing closer ties with Wellesley College. Much of our attention this year was centered on the Modern Languages where the strengths of M.I.T. and Wellesley are to some extent complementary. A member of the Wellesley French Department taught part time at M.I.T. this year in the existing program; in addition a Wellesley faculty member offered, for the first time, Wellesley courses in Chinese actually given on the M.I.T. campus. Furthermore there were a considerable number of discussions between Wellesley and M.I.T. about future cooperation in languages. A Wellesley faculty member served on the selection committee for a Director of the Modern Languages, and the Dean of Wellesley College also participated in the selection process. Arising out of a parallel series of discussions, an arrangement was made whereby a number of Wellesley courses were recognized for distribution credit by the Committee on the Institute Requirement in the Humanities, Arts, and Social Sciences. We hope for much more interchange of faculty between Wellesley and M.I.T. in ensuing years and will particularly welcome the three members of the Wellesley faculty who will teach at M.I.T. in the Foreign Languages program next year.

The Committee on the Institute Requirement in the Humanities, Arts, and Social Sciences had a busy but relatively uncontroversial year. Dr. Louis Menand chaired the committee in the fall and Professor Leon Trilling in the spring. The requirement still seems to be functioning satisfactorily, though we are conscious of the need to give freshmen and freshman advisors more guidance than they currently receive. As the list of approved distribution subjects lengthens it is clear that newcomers to M. I. T. are finding it more and more difficult to understand just what the rationale of the distribution subjects is. However, the widespread interest in the importance of students' writing has encouraged the committee to be increasingly stringent in its interpretation of the criteria to be applied, because by distinction, distribution subjects are intended to require that students write a good deal.

Discussions about the best way of developing teaching and research on the social and value aspects of science and technology have continued throughout the year, as they have since early in 1973. The offerings of the Technology Studies Program have clearly met with an encouraging response from students. How best to relate the work of the Technology Studies Program with that envisaged by Professor Elting Morison and his colleagues, whose appointments in the context of a prospective College of Science, Technology and Society were announced last year, had not been decided by the time this report was written. Meanwhile I should like to thank Professor Louis Bucciarelli for his work as Director of the Technology Studies Program for the past three years. He returned to M. I. T. from a leave of absence at the Smithsonian Institution especially to take on this task, and will move on to a regular appointment in the School of Engineering on July 1, 1977. He will, however, continue to be associated with the Technology Studies Program. This will not be true of Professor Nathan Sivin who has taught at the Institute since 1964, latterly as Professor of the History of Science and of Chinese Culture in the School. We have always known that the lure of an oriental studies department might some day be too strong for him to resist. That we are now losing him to a joint appointment in Oriental Studies and in the exceptionally strong History of Science and Technology program at the University of Pennsylvania, is a source of great regret. He has been a source of strength to the School and I personally am very sorry to see him go.

Professor Carl Kaysen joined the School as Visiting Professor of Political Economy from the Institute of Advanced Study at the beginning of the year and became Skinner Professor in the School in January. Beginning in July 1977, he will become the Director of a new off-campus project which will be of great interest to many M. I. T. faculty. This is a study of relations between government and higher education in America, an area which he has firmly made his own in recent years. The study will be sponsored by the Alfred P. Sloan Foundation.

HAROLD J. HANHAM

TABLE I

Enrollment in Distribution Subjects: 1976-77

Field	# of Subjects	Year 1	Year 2	Year 3	Year 4	Year 5 & Graduate	Total M.I.T.	Wellesley	Harvard	GRAND TOTAL	%
History of Art	7	76	106	117	89	32	420	5	2	427	10.0%
Humanities:	58	989	802	552	332	18	2,693	6	0	2,699	63.5%
American Studies	1	5	2	3	1	0	11	0	0	11	0.3%
Anthropology/Archaeology	3	79	66	34	17	1	197	0	0	197	4.6%
Creative Writing	2	27	19	21	17	0	84	0	0	84	2.0%
Crossroads	7	48	58	39	28	0	173	0	0	173	4.1%
Foreign Languages	12	85	94	62	24	5	270	0	0	270	6.4%
History	13	227	161	134	70	4	596	1	0	597	14.0%
Literature A. (English)	9	192	150	106	73	3	524	1	0	525	12.3%
Literature B. (Foreign Language)	4	15	11	10	8	3	47	0	0	47	1.1%
Music	5	287	202	122	73	1	685	4	0	689	16.2%
Technology Studies	3	24	39	21	21	1	106	0	0	106	2.5%
Philosophy and Linguistics	11	267	166	121	63	1	618	2	0	620	14.6%
Political Science	6	142	70	59	28	1	300	3	1	304	7.1%
Urban Studies	4	27	45	46	17	1	136	5	0	141	3.3%
Visual Arts and Design	1	15	41	4	4	0	64	0	0	64	1.5%
<u>TOTAL</u>	<u>88</u>	<u>1,516</u>	<u>1,230</u>	<u>899</u>	<u>533</u>	<u>53</u>	<u>4,231</u>	<u>21</u>	<u>3</u>	<u>4,255</u>	<u>100.0%</u>
%		35.6%	28.9%	21.1%	12.5%	1.3%	99.4%	0.5%	0.1%	100.0%	

Enrollment data are taken from the Registrar's fifth-week report.

TABLE II

Enrollment in Humanities, Arts, and Social Sciences Elective Subjects: 1976-77

Field	# of Subjects	Year 1	Year 2	Year 3	Year 4	Year 5 & Graduate	Total M.I.T., Wellesley Harvard	GRAND TOTAL	%	
Economics	26	256	484	469	302	48	1,559	9	3	26.4%
History of Art	1	0	1	4	1	3	9	0	0	0.1%
Humanities:										
Anthropology/Archaeology	9	0	5	12	20	2	39	1	0	0.7%
Foreign Lang. & Lit.	28	149	116	141	92	52	550	1	0	9.2%
History	19	12	40	60	43	6	161	8	1	2.9%
Interdisciplinary	21	13	20	41	35	6	115	23	0	2.3%
Literature	32	32	117	145	158	4	456	18	0	8.0%
Music	22	44	120	101	81	10	356	2	1	6.0%
Technology Studies	11	10	23	34	38	2	107	3	7	2.0%
Writing	17	81	165	143	120	10	519	4	2	8.8%
	<u>159</u>	<u>341</u>	<u>606</u>	<u>677</u>	<u>587</u>	<u>92</u>	<u>2,303</u>	<u>60</u>	<u>11</u>	<u>39.9%</u>
Philosophy	16	14	47	77	67	16	221	2	14	4.0%
Political Science	34	32	130	183	161	5	511	103	6	10.4%
Psychology	11	72	217	222	162	7	680	23	2	11.8%
Urban Studies	12	1	37	67	28	13	146	23	1	2.9%
Visual Arts	16	13	58	50	64	29	214	26	6	4.1%
Subjects in Other Schools	4	4	5	4	5	1	19	3	2	0.4%
<u>TOTAL</u>	<u>279</u>	<u>733</u>	<u>1,585</u>	<u>1,573</u>	<u>1,377</u>	<u>214</u>	<u>5,662</u>	<u>249</u>	<u>45</u>	<u>100.0%</u>
%		12.3	26.6	29.4	23.1	3.6	95.0	4.2	0.8	100.0%

The figures include all subjects listed in the catalogue as routinely eligible toward the Institute Requirement. Other subjects approved by petition have not been counted. The data are taken from the Registrar's fifth-week report.

TABLE III

Fields of Concentration Selected

Under the Humanities, Arts, and Social Sciences Requirement

<u>FIELD</u>	<u>YEAR</u>				<u>TOTAL</u>
	1977	1978	1979	1980	
Anthropology/Archaeology	5	10	2	0	17
Creative Writing	39	49	20	2	110
Crossroads	7	4	2	1	14
Economics	207	125	37	3	372
Foreign Languages	46	25	9	0	80
History	46	45	11	0	102
History of Art	8	4	1	0	13
Labor in Industrial Society	4	2	0	0	6
Linguistics	0	4	1	0	5
Literature	70	24	4	1	99
Music	54	51	15	2	122
Philosophy	66	34	20	0	120
Political Science	106	59	16	0	181
Psychology	150	84	19	1	254
Technology Studies	4	8	10	1	23
Urban Studies	14	6	7	0	27
Visual Arts and Design	31	10	6	0	41
Special Concentrations	<u>19</u>	<u>7</u>	<u>4</u>	<u>0</u>	<u>30</u>
TOTAL	868	547	183	11	1,603

TABLE IV

Undergraduate Majors in the School of Humanities and Social Science*

<u>Year</u>	<u>Economics</u>	<u>Humanities</u>	<u>Philosophy</u>	<u>Political Science</u>	<u>TOTAL</u>
1966-67	76	121	--	73	270
1967-68	81	148	--	76	305
1968-69	84	195	--	79	358
1969-70	68	200	--	85	353
1970-71	60	162	--	59	281
1971-72	63	124	13	38	238
1972-73	64	92	15	39	210
1973-74	55	67	10	30	162
1974-75	63	48	1	14	126
1975-76	67	41	3	24	135
1976-77	67	31	7	25	130

TABLE V

Graduate Students in the School of Humanities and Social Science**

<u>Year</u>	<u>Economics</u>	<u>Linguistics</u>	<u>Philosophy</u>	<u>Political Science</u>	<u>Psychology</u>	<u>TOTAL</u>
1966-67	117	42	29	79	26	293
1967-68	114	31	27	80	27	279
1968-69	118	38	23	87	27	293
1969-70	117	41	31	82	41	312
1970-71	103	34	36	78	23	274
1971-72	104	40	29	70	29	272
1972-73	109	34	24	82	23	272
1973-74	114	33	21	96	25	289
1974-75	114	35	18	95	25	287
1975-76	120	33	16	89	27	285
1976-77	114	32	14	91	29	280

*As registered in the second term of academic year 1966-67 to 1976-77 (omitting freshmen and undesignated sophomores)

**As registered in the second term of academic year 1966-67 to 1976-77 (including special graduate students)

Department of Economics

No major new initiatives were taken this academic year, 1976-77, but some important past decisions were further monitored and implemented. Modification of the Department's administrative structure through the addition of an Associate Department Head, so ably filled this first year by Professor Peter A. Diamond, and an expansion of the committee structure have resulted in improved functioning of the Department.

The undergraduate and graduate student bodies have remained essentially unchanged in size over many years, although the number of degree recipients has fluctuated a good deal. Enrollment in subjects that satisfy the Institute's Humanities, Arts, and Social Sciences Requirement which was modified three years ago, however, has increased substantially. Excluding labor subjects, which are usually taught by the Industrial Relations Section of the Sloan School of Management, undergraduate enrollment in these subjects has increased from about 1,100 in the early 1970s to 1,500 in the last two years -- a 39 percent increment. The introductory economics subjects have been substantially revised over this period and one-third more students are completing the entire introductory year. New intermediate subjects of an interdisciplinary character have been added, such as 14.21 Health Economics and 14.24 Law and Economics, and older subjects substantially revised, such as 14.03 Applied Microeconomics, with noticeable student response.

The Undergraduate and Graduate Economics associations have been unusually active in the last two years with increased attention to curricula reform and more social hours. An Adam Smith "Roast" held on the bicentennial of the publication of the Wealth of Nations attracted more than 250 to a dinner featuring many visiting economists, and an economists' tennis exhibition in honor of Irving Fisher featured local and visiting faculty.

Two major conferences were organized by members of the faculty: one arranged by Professor Jagdish Bhagwati on the New International Economic Order attended by some 50 distinguished economists from all over the world; the other by Professor Ann F. Friedlaender on Air Pollution and Administrative Control that had more than 100 participants from economics, law, political science, and public administration. Both conferences will make their proceedings available in published form.

RESEARCH

A major research activity of a large number of faculty was the analysis of particular industries or industrial problems. Energy questions involved the largest single group: Professor Morris A. Adelman on the world oil market; Professor Martin L. Weitzman on OPEC and oil prices; Professor Paul L. Joskow on various aspects of the nuclear energy industry, on the future of the electric utility industry, and on the interaction between nuclear regulation and electric utility prices and fuel consumption; and Professor Jerry A. Hausman on the demand for energy conservation. Other faculty examined aspects of other industries: Professor Jeffrey E. Harris -- the organization and efficiency of hospitals in delivering health care; Professor Peter Temin -- the drug industry; Professor Weitzman -- the

optimal (theoretical) development of resources; and Institute Professor Robert M. Solow -- extraction costs in the theory of exhaustible resources, and optimal fishing; Professor Friedlaender -- strategies in transport policy and on regulation and technological change in the railroad industry.

International finance has especially occupied the attention of Professors Rudiger Dornbusch and Charles P. Kindleberger who have analyzed the problem arising from flexible or fixed exchange rates, balance of payments problems, international capital movements, and the characteristics of a satisfactory international money; while Professor Lance Taylor has emphasized the contractionary aspects of a devaluation. In the closely related economic development area, Professor Taylor also is exploring the relationship of nutrition to economic development; Professor Bhagwati has several pieces of work on the impact of the brain drain; and Professor Richard S. Eckaus is following out the relationship of finance and planning to economic development.

In macroeconomic stabilization policy, Professor Robert E. Hall and Institute Professors Franco Modigliani and Solow have analyzed many aspects of stabilization policies: the efficiency of fiscal policy, the impact of temporary tax changes on aggregate demand, the contribution of manpower programs to the easing of inflationary pressures, and the role that indexation could play in stabilization policy.

Professors William C. Wheaton and Jerome Rothenberg have written several papers on urban transportation, its effect on urban location and rents, and on the determination of housing demand. The econometric problems of dealing with truncated distributions in social experiments, such as the New Jersey income maintenance experiment, have been explored in depth by Professor Hausman. Professor Temin has continued his study of the economics of slavery in the South and the rate of recovery of the South from the Civil War.

In the area of microeconomic theory, Professor Franklin M. Fisher has extended his work on the stability of equilibrium, and Professor Robert L. Bishop is revising his microtheory textbook manuscript. While covering many areas of microeconomics, finance, capital theory, history of economic thought, and social welfare functions, Institute Professor Paul A. Samuelson's research has concentrated more particularly on nonlinear systems and stochastic population processes. Professor Diamond continues his theoretical work on uncertainty and taxation, and Professor Friedlaender on tax incidence. More applied work in public finance has been carried out by Professor Diamond on the Social Security system, by Professor Evsey D. Domar on interpersonal transfers, by Professor Lester C. Thurow on income distributions and poverty, and by Professor E. Cary Brown on tax structures.

Publications

Much of the research reported here has appeared in professional journals or as chapters in symposium volumes. In addition, books published this year (besides those on pollution and the international order already referred to) were: a monograph entitled Appropriate Technologies for Developing Countries by Professor Eckaus for a Panel of the National Academy of Sciences; the sixth edition of the successful text, Government Finance, coauthored by Professor Friedlaender; the publications by Professor Kindleberger, as coeditor of Multinationals from Small Countries and coauthor of the third edition of his text Economic Development, and the E.S. Woodward Lectures in Economics, The International Monetary System (University of British Columbia); the eighth edition of Personnel Administration by Professor Myers with Emeritus Professor Paul Pigors; and Volume IV of Institute Professor Samuelson's Collected Scientific Papers.

FACULTY

Visiting faculty this year included Professors Thomas J. Rothenberg of the University of California at Berkeley, for the whole year, and for the spring term, Avinash Dixit of the University of Warwick, William Poole of Brown University, and T.N. Srinivasan of the University of Delhi and the World Bank. Regular faculty on leave were Professors Peter Temin, who spent the year at the Charles H. Warren Center at Harvard University, Stanley Fischer, in Israel for the year, and Hal R. Varian, at Stanford University, and the University of California at Berkeley, in the spring term.

It is a pleasure to report the appointment of Professor Richard S. Eckaus as Ford International Professor of Economics to replace Professor Emeritus Kindleberger; the promotions to Professor of Stanley Fischer, to Associate Professor with tenure of Paul L. Joskow and Rudiger Dornbusch, and to Associate Professor of William C. Wheaton, a joint appointee with the Department of Urban Studies and Planning. Several junior faculty are being added next year to relieve some of the pressures of our expanded enrollment. New Assistant Professors will be: Marilyn J. Simon and Henry S. Farber from Princeton University, Eric S. Maskin from Harvard and Cambridge universities, Kevin W.S. Roberts from Oxford University, and Harry C. Katz from the University of California at Berkeley, a joint appointee with the Sloan School. Unfortunately we will lose Professor Hal R. Varian who has resigned to accept a full professorship at the University of Michigan.

Institute Professor Modigliani completes his term this year as president of the American Economic Association. Professor Franklin M. Fisher begins a two-year term as vice president of the Econometric Society, and terminates his long service as editor of Econometrica. Professor Weitzman was elected a fellow of the Econometric Society. Institute Professor Samuelson received a D.H.C. from the Catholic University of Louvain, Belgium, and an LL.D. from Emmanuel College. Institute Professor Solow received an LL.D. from Lehigh University, is the president-elect of the American Economic Association, and was selected for the James R. Killian, Jr. Faculty Achievement Award for 1977-78 in recognition of his "extraordinary professional accomplishments."

E. CARY BROWN

Department of Humanities

The Department of Humanities experienced a very challenging year during 1976-77. It was faced with more than the usual array of pedagogic and administrative issues and tasks. On one side, for example, it had administratively to absorb the Foreign Languages and Literatures Section, as well as to accommodate the Writing Program as a long-term addition. On another side, pedagogically, it had to participate in the debates over the nature of the Writing Program, as well as in further efforts to define the role of literature, music, etc. at the Institute. I like to think that out of these challenges has come growth in quality as well as quantity for the Department.

Foreign Languages and Literatures has been undergoing a reorganization of sorts as it becomes integrated administratively and intellectually into the life of the Department. Associate Dean Donald Blackmer has served with great distinction, devotion, and tact as Acting Head of the Section during this period of transition; in his part of this report, he outlines the specific changes in personnel and offerings that have occurred. Here, I should like to note the appointment, after a thorough search conducted by a committee under Dean Blackmer's guidance, of Margery Resnick as head of the Foreign Languages and Literatures Section, starting 1977-78. Professor Resnick, from Yale, promises to bring strong administrative talents to her job, as well as establishing useful intellectual links with the Literature Section and other parts of the Department and the Institute. A concern for the teaching of language, with an eye to linguistics, remains central to her task.

Special notice must here also be given to the Writing Program. By decision of the Dean, it has been firmly placed, administratively, in the Department. After a good deal of debate and publicity, often acrimonious, policy for the future development of the Writing Program has been worked out and decided upon (see David Breakstone's report). A special committee, chaired by Professor Leo Marx, has been formed to search for a long-term head of the Program. In the area of science writing, Rae Goodell has been appointed an Assistant Professor. Another committee, chaired by myself, has been conducting a search for at least three new appointments in general writing and one in technical writing. The number of fine candidates is impressive and reassuring. An expanded writing program, with agreed upon goals, and a unified esprit de corps, is now gathering momentum, and we are sanguine of its success. While many problems lie ahead -- types of writing subjects to be offered, budgetary needs, relations of the writing staff to the Literature Section staff, etc. -- we appear on our way, with reasonable goodwill on the part of all concerned, to solving them.

An appointment in Black Literature and General Literature was contemplated for the coming year, but the search was handicapped by a late start in the spring and did not end with the selection of a satisfactory candidate. Next fall, however, we shall have Professor Samuel Allen of Boston University as a Visiting Professor in Black Literature and, in the spring, Assistant Professor Nellie McKay of Simmons College in the same capacity. A vigorous search for a full-time appointment will be resumed in the fall.

In the Literature Section, the addition of Professors Irene Tayler and David Thorburn as tenured members has been most welcome, as the Section grows in intellectual vigor and pedagogic strength. Stephen Tapscott will join them next year as an Assistant Professor. Under the guidance of Professor Alvin Kibel, head of the Section, a most successful Literature Workshop (see his report) has been established, with faculty members from the surrounding Cambridge-Boston universities participating. Plans are now under way to expand this workshop, and to reach out to students as well as faculty.

The History Workshop, under the direction of Professor Alex Keyssar, devoted itself to methodological and theoretical problems confronting those who study industrial society in historical perspective, with eight guest lecturers talking about particular approaches to the subject. It is with great regret that I must acknowledge the resignation from the Department of Professor Keyssar, who is leaving to take up a most attractive offer from Brandeis University.

A Committee on Drama has been appointed, chaired by Professor Albert R. Gurney, Jr., to make long-range plans for the development of drama in the Department and at M.I.T. Its first specific business was to make an appointment of an Assistant Professor of Drama and Theatre Arts. A full-scale search was successfully concluded with the appointment of Robert Scanlon, who, we are proud to note, was not only the best candidate but a graduate of M.I.T.!

It is good to report that the concentration in Ancient and Medieval Studies was approved by the Committee on the Humanities Requirement, and we look forward to a successful first year. Discussions were held with the Committee on Curricula (C.O.C.) concerning the number of nine- and 12-unit subjects to be offered by the Department, and an agreement reached for the future.

Beginning discussions also have been held with the M.I.T.-Wellesley Exchange Committee, to foster relations among those concerned with humanities at both campuses, as well as to iron out overlaps and potential problems in relation to Wellesley proposed Distribution subjects. More discussions will be needed next year.

It is always sad to lose long-time colleagues. This year we lose to early retirement Lecturer Primus Bon and Professor E. Neal Hartley. Professor Joseph Everingham will be partly retiring, due to health reasons, but will still be able to direct major drama shop productions for us next year. Professor Klaus Liepmann comes to the end of his active service as an emeritus professor, and we shall miss his presence in the classroom. I cannot help adding a special note about my friend and colleague, Neal Hartley. Not only has he served with distinction in the History Section, but he has left his mark on the affairs of the Department at large as well, where his wisdom and long-term knowledge of Institute-wide affairs has been invaluable.

Again, the Department has enjoyed the generous benefactions of the Friends of Humanities, which continues under the unflagging enthusiasm and leadership of I. Austin Kelly. Without the financial support of the Friends, we would not have been able to proceed with the Literature and the History Workshops, as well as a host of other activities. Without the moral support of the Friends, we would be poorer in morale.

The immediate future poses a number of challenges for the Department. We have made a number of key appointments that definitely strengthen our pedagogic and intellectual posture at the Institute. We must continue in this direction. New initiatives, such as the Literature and the History Workshops, must be sustained and expanded. We are in the process of integrating new programs or sections into the Department, e.g., the Writing Program and Foreign Languages and Literatures; further integration and the development of interdisciplinary links are in order. Outside the Department, productive relations with other parts of the School and the Institute must be more sharply defined, e.g., with the developing New College, with Technology Studies, and with various initiatives in the Engineering and Science Schools seeking to integrate their fields and the Humanities. It is pleasant to report that the Department of Humanities will confront these challenges, and invitations, from a position of growing confidence and strength.

BRUCE MAZLISH

ANTHROPOLOGY/ARCHAEOLOGY PROGRAM

In addition to the ongoing teaching and research activities of its faculty members, the Anthropology/Archaeology Program was involved in two important undertakings during the 1976-77 academic year that are expected to generate new and stimulating directions for the Program on both the educational and research fronts.

First, discussions are well under way with members of the Anthropology Department at Wellesley College to coordinate the teaching programs of the two institutions so that a broader and more unified offering in anthropology/archaeology will be available to students. Collaboration is expected to include decisions arrived at jointly about the nature and scheduling of subjects; seminars for upper-level majors and graduate students to be taught by faculty members from both schools and including several distinguished guest lecturers; and joint teaching of lower-level subjects on themes of particular importance to anthropology to be accompanied by a series of public lectures of interest to the general academic community.

Secondly, several years of continued effort on the part of the Program's archaeologists (Professors Heather Lechtman, Arthur Steinberg, and Wilma Wetterstrom) to establish together with colleagues at eight other Boston-area cultural and educational institutions, an inter-institutional Center for Materials Research in Archaeology and Ethnology are expected to culminate in the establishment of the Center during the summer months of 1977. In two substantial grants to the Center, the National Endowment for the Humanities will support an initial three-year planning and teaching stage during which time the Center's research laboratories will be developed. The creation of the Center is an important step in providing archaeological research with a fundamental grounding in the science of materials, organic and inorganic. The Center's establishment should make M.I.T. a national leader in the field of materials research in archaeology, ethnology, and related disciplines.

Professor Lechtman focused her energies during 1976-77 on matters concerning the Center for Materials Research in Archaeology and Ethnology. She served as coordinator for all aspects of the Center's activities, including its second year of graduate seminar-laboratory teaching (on the subject of Food Production in Ancient Societies) and the preparation of several grant proposals for funding the Center's research and teaching programs. She was chosen to be the first Director of the Center by its Steering Committee. Professor Lechtman successfully completed her research on north Peruvian metallurgy of the pre-Columbian period, supported by a grant from the Tinker Foundation, and submitted a proposal to the National Science Foundation (NSF) for an 18-month major research project on the comparative bronze metallurgies of the Old and New Worlds. She was elected to membership in the Institute of Andean Studies in Berkeley, and became vice president of the Institute of Andean Research in New York City.

Professor James Howe spent a good deal of time planning and obtaining funds for an intensive study of political behavior and political events among the San Blas Cuna peoples of Panama to be carried out during a leave of absence in 1977 and 1978. He was successful in obtaining grants from the Social Science Research Council and the Old Dominion Foundation.

Professor Wetterstrom was promoted to Assistant Professor of Anthropology in July 1976 after receiving her Ph.D. from the University of Michigan. She is now revising her dissertation for publication as a monograph. During the year, she presented some of her work at two professional meetings. She is currently involved in three research projects: analyzing how food processing techniques influenced human evolution; studying archaeological plant remains from sites in Southwest Texas; and working with Professor Umesh Banergee of the University of Massachusetts at Boston on applications of the scanning electron microscope in archaeological botany. At M.I.T. this year, Professor Wetterstrom served on the Committee for the Institute Requirement in the Humanities, Arts, and Social Sciences. As part

of her teaching responsibilities, she participated in the graduate seminar on Food Production in Ancient Societies offered as part of the teaching program of the Center for Materials Research in Archaeology and Ethnology. She helped organize and teach the seminar and, in conjunction with it, taught a laboratory subject on archaeological botany with Professor Lawrence Kaplan of the University of Massachusetts at Boston.

Professor Shelton H. Davis was Visiting Professor of Anthropology during the academic year 1976-77. To date, Professor Davis' main area of research has been on the contemporary situation of American Indian tribes, and one of the subjects he taught concerned North American Indian peoples. Professor Davis is also Director of the Anthropology Research Center (ARC, Inc.) in Cambridge. Recently, he submitted a grant application to the Massachusetts Foundation for Humanities and Public Policy titled "New England and the Energy Crisis: The Nuclear Power Controversy in Massachusetts." The idea for this project grew out of Professor Davis' 1977 I.A.P. course on the same topic, and his participation in an M.I.T. Department of Physics seminar on "Science and the Public Interest."

Professor Joseph Hall also was Visiting Assistant Professor of Archaeology during the 1976-77 academic year. He taught subjects in Industrial Archaeology, Archaeology of the Ancient Mediterranean, New England Archaeology, and Approaches to Archaeology, the latter taught together with Professor Wetterstrom. Professor Hall established M.I.T.'s first archaeological field program in collaboration with the Department of Anthropology at Wellesley College. The site chosen for excavation was the Henry Wood's Sons Mineral Paint Manufactory, located on the Wellesley College campus. Students were trained in topographic mapping, transit survey, excavation techniques, and the preparation of field drawings. They excavated on Fridays and Saturdays during spring term. Students from both schools participated in the fieldwork, and at times, 20 students were working at the site. Professor Hall presented a preliminary report on the excavations at the Sixth Annual Meeting of the Society for Industrial Archaeology in Wilmington, Delaware.

Professors Steinberg, Martin Diskin, and Jean Jackson were on leave during the 1976-77 academic year.

Professor Diskin completed the second of his two-year leave of absence. During that time, he conducted field research in Oaxaca, Mexico. His work involves the relationship between sociocultural and nutritional factors in a small peasant-Indian community. Specifically, he collected data on agricultural production, food use in daily and ceremonial contexts, and family birth and death histories. He is testing several hypotheses that relate the actual form of production to availability and use of food. The next phase of his work involves certain measures of nutritional status of the members of the sample population of 35 families. He and a Mexican colleague have submitted a grant proposal to the NSF under its cooperative science program for Latin America to support the second phase of their research.

Professor Steinberg spent his leave analyzing the data he collected in the field and in the laboratory on the ancient copper smelting industry of the island of Cyprus. He also has prepared a paper with Diana Kamilli on their joint research conducted at M.I.T. in 1975-76 on early Mesopotamian ceramics.

Professor Jackson was promoted to Associate Professor of Anthropology. Her promotion spurred her on in writing a book entitled The Bará: Individual and Group Identity in Tukanoans of the Northwest Amazon, based on her fieldwork among the Bara several years ago. She spent her leave of absence preparing this manuscript for publication, and her work was supported in part by an Old Dominion Fellowship. Professor Jackson attended the XLII Congrès International des Américanistes in Paris in September 1976 and the annual meetings of the American Anthropological Association in Washington, DC in November.

Publications

Professor Lechtman coedited a book with Robert S. Merrill entitled Material Culture: Styles, Organization and Dynamics of Technology, which was published in June 1977. Her article "Style in Technology" appears in that book. She has completed a paper on "Metallurgy of the Central Andes" which will appear as a chapter in the Yale University Press book, The Coming of the Age of Iron, a festschrift being prepared in honor of Cyril Stanley Smith.

Professor Howe coedited a volume on Ritual and Symbolism in Native Central America in the University of Oregon Anthropological Papers series. His article "Carrying the Village: Cuna Political Metaphors" appeared in a book entitled The Social Use of Metaphor, published in 1977 by the University of Pennsylvania Press. He has also written two articles and a critical note, and he finished work on a book of Cuna oral literature, to be published in late 1977 by the University of Panama Press.

Professor Wetterstrom published a popular article, "They Never Savored Chili" which appeared in Exploration, the journal of the School of American Research in Santa Fe. Another of her articles, "Plant Foods from the Gypsy Joint Site" is scheduled to appear in the Academic Press book on Prehistoric Patterns of Human Behavior: A Case Study in the Mississippi Valley edited by Bruce D. Smith, which is in press.

Professor Davis coauthored a 106-page report titled "The Geological Imperative: Anthropology and Development in the Amazon Basin of South America." His book Victims of the Miracle: Development and the Indians of Brazil will be published by Cambridge University Press in the fall.

Professor Steinberg published a paper entitled "Technology and Culture: Technological Styles in the Bronzes of Shang China, Phrygia and Urnfield Central Europe," which appeared in the book Material Culture: Styles, Organization and Dynamics of Technology.

Professor Jackson published an article on "Bará Zero-Generation Terminology and Marriage" which appeared in the journal Ethnology in January 1977.

HEATHER LECHTMAN

FOREIGN LANGUAGES AND LITERATURES SECTION

This first full year since the foreign languages and literatures group joined the Department of Humanities has been a busy and productive one. The most noteworthy event was the selection, after a nationwide search, of Professor Margery Resnick of Yale University as Director of Modern Languages and head of the Section. Professor Resnick, whose scholarly field is 20th-century Spanish poetry, will be teaching Spanish language and literature in addition to her administrative duties. Her arrival will thus help meet a long-standing student demand for teaching in Spanish, a subject which has hitherto been offered only at the elementary level.

We continued this fall the process begun last year of outside evaluation of parts of our language program. Last spring Professor Emeritus Nelson Brooks of Yale spent several days reviewing our offerings in French; this fall Professor Robert Spaethling of the University of Massachusetts did the same for German. Useful suggestions for improvements were made, especially the need in both cases to expand our offerings at the intermediate level, between the more advanced language subjects and the subjects principally oriented toward literature. To that end we have introduced a "composition and conversation" subject in both French and German and are developing new subjects concerned with historical and contemporary aspects of French and German cultures.

Another important recommendation made by both outside evaluators was the desirability of strengthening the teaching staff by the addition of several people at the assistant professor level. It was decided to defer this task until a Director of Modern Languages had been selected and to fill vacancies by appointing instructors on a one-year basis for the coming year. The selection of at least one assistant professor in French, German, and Russian will be high on the agenda next year. As we discovered during the limited searches undertaken this year to fill temporary positions, the supply of impressively qualified language and literature teachers with recent Ph. D. s is unusually large right now, giving us an excellent opportunity to build a staff of the highest possible quality.

One promising direction in which we have moved in seeking to enrich the foreign languages and literatures program has been toward greater cooperation with Wellesley College in the context of the Wellesley-M. I. T. Exchange relationship. The greatest initial opportunity for collaboration appeared to be in French, where Wellesley has a particularly strong and diverse program. During the past year Professor Barry Lydgate of the Wellesley French Department joined the Section on a half-time visiting basis; next year he will be with us full time, and will be joined for one semester by his Wellesley colleague Professor Isabelle de Courtivron. Another member of the Wellesley department, Professor Carlo Francois, will offer one of his regular Wellesley subjects at M. I. T., and one of Professor Lydgate's subjects will alternate weekly between the two campuses. As a further tangible sign of the commitment to institutional collaboration in the foreign language area, Professor Yih-jian Tai of the Wellesley Chinese Department will continue to teach two subjects on the M. I. T. campus, one in Beginning Chinese, the other in Chinese for the Bilingual. This arrangement will help satisfy the substantial demand -- in particular from the numerous students of Chinese extraction at the Institute -- for instruction in Chinese on the M. I. T. campus.

Deserving of special mention among the several staff changes this year are the resignations or retirements of three long-term lecturers: Primus Bon in German, Stella Greenfield in French, and Magda Tisza in both German and French. Each has taught language at M. I. T. with skill and dedication for roughly 20 years, and each will be missed. The coincidence of their joint departure seemed to their colleagues to mark the end of an era, especially given the retirement earlier in the year of Margo Pelkey, who had served as secretary and administrative officer of the former Department of Foreign Literatures and Linguistics for many years. Another noteworthy event of a different sort was the granting of tenure to Professor Catherine Chvany in recognition of her distinguished scholarly work in Slavic syntax and her effectiveness as a teacher of Russian and coordinator of our Russian language offerings.

DONALD L. M. BLACKMER

HISTORY SECTION

The History Section is again pleased to report a steady increase in student enrollment. The fall term, 1976 saw 12 courses drawing 330 students, whereas the 18 courses given in spring, 1977 produced the highest figure in recent years, 455. The total of 785 for the year compares with 643 in 1975-76 and 417 for 1974-75.

The established 21.300 and 21.301 Modern World History I and II, attracted 124 and 126 students respectively, and the newly introduced 21.302 The Ancient World, which was given each term, drew 85 and 92. Continuing to prove popular with our undergraduates was 21.304 The Middle Ages, with figures of 49 and 52.

The number of students concentrating in history to satisfy their Humanities Requirement rose by almost 50 percent, going from 70 in 1975-76 to 102 this year.

Newcomers to the ranks of those teaching courses in the Section included: Professor Kenneth Keniston, holder of the Mellon Chair, who offered a course on Youth Movements; Professor Carl Kayssen, who holds the Skinner Chair, taught Inequality in America; and Professor Alex Keyssar, who, in addition to teaching, directed a series of workshops focusing upon the history of industrial society. Sponsored by the Department of Humanities, these workshops represent a portion of the effort to establish at M.I.T. a teaching and research group to study industrial societies in an historical perspective. The workshops were open to invited guests and interested M.I.T. and Wellesley students and faculty and were held in the new History Workshop room.

Professor Arthur Kaledin remained on leave of absence during the entire academic year, and Professor Lewis Wurgaft was absent for fall term.

It is with profound regret and a deep sense of personal loss that I must report that Professor E. Neal Hartley has chosen early retirement effective July 1, 1977. Professor Hartley has been a stalwart in the history corps since 1945. Archivist of the Institute, he also served as former Secretary of the Faculty and was Acting Head of the Department of Humanities for one year.

Professor Thomas Mahoney traveled to the People's Republic of China in November as part of a 15-person fact-finding mission, and also visited Japan. In March 1977, the New England Engineering Society honored him as "Man of the Month." Professor Bruce Mazlish was invited to be the Remsen Bird lecturer during spring semester at Occidental College in Los Angeles. While on the West Coast, he also was invited to give seminars and lectures at the Los Angeles, Santa Barbara, and San Diego campuses of the University of California, as well as at the Center for Democratic Institutions. In March, he gave a lecture, "Psychoanalytic Theory and History: Groups and Events," as part of a special series sponsored by the University of Chicago and the Chicago Institute for Psychoanalysis. In December, at the annual American Historical Association (AHA) meeting, he gave the luncheon address at the first such meeting of the Group for the Use of Psychology in History, an affiliate organization of the AHA; his address was entitled, "Reflections on the State of Psychohistory," and was subsequently published in the March 1977 issue of The Psychohistory Review. Professor Monroe Little, Jr. gave a paper on "Questions of Class and Culture; the Social and Economic Origins of the Black College Student" at the 1977 Annual Meeting of the National Conference of Black Political Scientists in Atlanta. Professor David Ralston participated in a summer project assessing the impact of the telephone on society. The study was under the Center for International Studies and was funded by the National Science Foundation.

Publications

Professor Mahoney published "Edmund Burke and the American Revolution" in John Browning and Richard Morton, eds., 1776 (Toronto: Samuel Stevens, 1977).

Professor Bruce Mazlish's book, Kissinger. The European Mind in American Policy, was published by Basic Books. His article, "Thrice-Born. A Psychohistory of Jimmy Carter's 'Rebirth'" (written with Edwin Diamond) appeared in New York magazine, August 30, 1976, and has enjoyed translation into German and Dutch.

Professor Harald Reiche's "Gallehus Horns, Lunar Declination Cycle, and Ragnarök" appeared in Prismata: Festschrift Willy Hartner (Wiesbaden: Steiner, 1977).

THOMAS H. D. MAHONEY

LITERATURE SECTION

During the past year, as is its habit, the Literature Section broadcast the name of M. I. T. and advertised the presence of a strong humanistic component therein at a variety of professional conferences and occasions. Professor Irene Tayler, for example, directed the Blake Seminar and Professor David Thorburn the seminar on popular media at the annual Modern Language Association meeting, the largest and most important annual gathering of the clans in literature, languages, and related disciplines; other members of the Section delivered papers at this and other meetings. In addition, Professor Tayler has been appointed chairman of the panel on literary biography at the English Institute, the most important annual conference on literary theory and criticism in America.

The past year witnessed the usual scattering of publication, by Professors Tayler, Ruth Perry, Theodore Wood, Louis Kampf, Barry Spacks, and Instructor Richard Mallette, among others. Professor Albert R. Gurney, Jr.'s new play, "The Middle Ages," had its premiere at the Mark Taper in Los Angeles and his novel, Entertaining Strangers, about teaching at an institution strongly reminiscent of M. I. T., was published by Doubleday. The Section was pleased to announce the receipt of four awards. The Rockefeller Playwright-in-Residence Award, given by the Foundation to distinguished playwrights in academic residence, was granted to Professor Gurney; Professor Thorburn is simultaneously in receipt of two prestigious awards, one from the Guggenheim Foundation and one from the Rockefeller, to pursue his study of the relation between television and the tradition of popular theater. (The extent of the honor carried by these three awards may be estimated by saying that the chances of receiving one of them is roughly 2,000 to one.) Professor Alvin Kibel was corecipient of a National Endowment for the Humanities Extension award to expand the work of the Cambridge Humanities Seminar.

The Section continued to tighten its offerings, structuring more closely both its concentration and distribution offerings. Its major innovation, however, was the institution of the M. I. T. Workshop in Literary Studies, a highly successful triweekly conference begun this spring, which the Section hopes will become an annual feature of the Boston-Cambridge intellectual scene. At each meeting, a distinguished literary scholar leads a discussion concerning his or her recent work as exemplified by an essay circulated in advance. The workshop membership involves 35 faculty from various institutions, including Harvard, Wellesley, Boston University, Tufts, Boston College, and the University of Massachusetts. The general subject of the first series of discussions -- entitled "Text and Context: The Middle Range of Criticism" -- concerned exploration of the relationship obtaining between individual literary works and the context (psychological, historical, sociological, or semiological) in which the critic sets it for study. There were five meetings, each heavily attended, and to judge by the list of new applicants, the workshop is on its way to enduring success.

ALVIN C. KIBEL

MUSIC SECTION

In the Music Section student enrollment continues to grow beyond the figures for previous years. Noteworthy is the increase in music history, theory, and special subject courses which were introduced during the last three years and in which a greater percentage of students participate than in the introductory music courses. Not only is there greater interest in advanced music studies, but also the degree of performing proficiency of

entering freshmen is remarkable. Among the 560 students participating in the activities of the M.I.T. Symphony, Concert Band, Choral and Chamber Music societies, fully one-third meet conservatory standards. This year for the first time an instrumental competition for a solo appearance with the M.I.T. Symphony Orchestra was held; the music faculty was confronted with the difficult task of choosing a winner from among 12 candidates.

The Music Section produced and sponsored 88 public events. Highlights of the Guest Artist Series were the Prague and Borodin quartets, the song recital by Susan Wyner, and the Spanish guitarist Narcisco Yepes.

The M.I.T. Chamber Players, Concert Band, and Thursday Noon-Hour Concerts provided the community with a wide variety of programs. An important event has been the first release of an M.I.T. Symphony recording on Vox label. This first disc of an anticipated series of four contains the Dance Symphony of Aaron Copeland and the Suite from the Ballet "The Incredible Flutist" by Walter Piston, with David Epstein conducting. The Choral Society under the leadership of John Oliver performed The Seasons of Josef Haydn, the Mass in F of Anton Bruckner, and the Mozart Requiem.

M.I.T. has been the sponsor of the International Conference on Computer Music, whose activities were focused around the M.I.T. Electronic Music Studio, which was established and is directed by Professor Barry Vercoe. The concert concluding the conference consisted of programmed works of the participants, including Professor Vercoe's Synapse for Viola and Computer.

Events sponsored by the Friends of Humanities brought the Albanian Polyphonic Singers and a Chinese instrumental ensemble to the campus. The former group -- a discovery of this writer's researches in ethnic music in Boston -- was also videotaped by the Oral History Group.

The activities of the faculty were manifold in scope and productivity. Professor David Epstein conducted four concerts of the Worcester Symphony and appeared as guest conductor with the St. Louis Symphony, in addition to his regular series in Harrisburg, Pennsylvania. Currently, he is on leave of absence to complete a cello concerto and other commissioned works.

Professor John Harbison's orchestra composition Diotoma was premiered by the Boston Symphony Orchestra, and among his other works the Elegiac Song was performed by the Berkshire Music Center, Gunther Schuller conducting. Professor Harbison is the recipient of a Guggenheim Fellowship to complete a piano concerto and other works commissioned by New York chamber groups.

During his leave of absence last fall, Professor John Buttrick devoted his time to concertizing in Israel, Switzerland, and Germany. Since his return he has played recitals in California, Colorado, and New England cities.

Professor Marcus Thompson has also been active, with many public appearances. He conducted the May concert of the M.I.T. Symphony Orchestra, was the viola soloist with the Harrisburg Symphony Orchestra, and gave recitals and lectures at Stanford and universities in Pennsylvania, Ohio, West Virginia, and Michigan.

Professor Martin Farren was named Visiting Composer for the 1976-77 academic year at the University of Wisconsin at Parkside. Among his works which received performance were Musica Tridentina and The Passage of Three Times, the latter premiered by the M.I.T. Symphony Orchestra.

Professor Rufus Hallmark continued his researches in his field of specialty, romantic song literature. He presented a paper on Schubert's Auf dem Storm at a meeting of the American Musicological Society in Washington and is currently involved in editing Bach Cantata 114 for Die Neue Bach Gesellschaft.

Among the lecturers and instructors, John Oliver prepared the Tanglewood Festival Chorus of the Boston Symphony Orchestra in performances of Berlioz' Damnation of Faust, Liszt's Faust Symphony, Ives' Fourth Symphony, and Roger Sessions' When Lilacs Last in the Dooryard Bloomed. These pieces were also recorded for Deutsche Grammaphon. Timothy Aarset has prepared scores of late Renaissance and early Baroque music for publication in the series Musica Sacra et Profana and also has written a scholarly study on improvisatory performance of the period.

Finally, Stephen Erdely continued his field activities in Boston ethnic music sponsored by the National Endowment for the Arts, and has given research papers on the subject at meetings of national and international societies.

While the faculty is enthusiastic about the interest and musical background of M.I.T. students, it is also aware of its responsibility to provide the type of music education commensurate with the standards of the Institute. These standards are currently threatened by a lack of adequate lecture rooms, a decline of funds for library acquisitions, and the need for greater encouragement and support for curriculum development. It is hoped, however, that such difficulties are only symptoms of a growing program. The Institute's overall appreciation of music as art, communication, and a branch of humanistic studies is our sound hope for continuing development.

STEPHEN ERDELY

THE WRITING PROGRAM

The Writing Program experienced a year of consolidation and clarification. The Committee to Evaluate the Pilot Writing Program, chaired by Professor Nathan Sivin, submitted its report to Dean Harold Hanham in June 1976. The Report contained 15 pages of recommendations which generally endorsed the mission and objectives of the Pilot Program. Those recommendations aimed to regularize and strengthen the Program in the long run.

An acting director, David Breakstone, was chosen from the teaching staff to assume administrative duties for one year and to coordinate changes during the transitional phase. The Program staff -- seven full-time and five part-time -- offered eight subjects in 22 sections in fall term and 12 subjects in 26 sections during the spring. Total student enrollment, 622 for both semesters, represented roughly a 12 percent decline from the figures of 1975-76, owing largely to the failure of Writing and Experience to regain Humanities Distribution credit. A new subject, Writing and Reading Short Stories, gained substantial student acceptance, with five different senior staff members teaching its six sections during the year.

Seven members of the staff had a hand in the writing and publishing of a collection of essays, Free Writing!, released in January by Hayden Book Company. The essays articulate a group approach to the teaching of writing sometimes employed in Program classes and workshops. Professor Patricia Cumming and Instructor Robin Becker published book-length collections of their own poetry, as well.

The Writing Program envisages a staff consisting almost entirely of full-time faculty during 1977-78, teaching an enlarged complement of subjects and sections under the four general rubrics: science writing, technical writing, creative writing, and writing for general education. Diversity of teaching methods and approaches will continue to be encouraged.

A committee to appoint a senior director has been established, chaired by Professor Leo Marx, and an appointment is hoped for sometime in the course of the coming academic year, 1977-78. A committee chaired by Professor Bruce Mazlish hopes to make at least three full-time junior appointments in general writing and one in technical writing during the summer. Rae Goodell has been appointed Assistant Professor to teach science writing, and to develop the field in general. The DeWitt Wallace Fund, Inc. has made a generous grant to support this work over the next five years.

DAVID BREAKSTONE

CAMBRIDGE HUMANITIES SEMINAR

The Cambridge Humanities Seminar continues as a collaborative effort of universities in the Boston-Cambridge area to enrich and diversify their curriculum offerings in the humanities. The program includes faculty from M.I.T., Boston University, Brandeis University, Tufts, and Wellesley, and represents a variety of disciplines. The Seminar is unique as the only continuing collaborative body of its kind in the area.

This year the Seminar developed and offered four subjects, all but one offered at M.I.T. Three of these were taught jointly by faculty members in different disciplines and, in two cases, at different universities. These courses appeared in the catalogues of all participating institutions and were open to students at all institutions on the basis of cross-registration.

The central colloquium of the Seminar continued its general investigation of secularism, modernism, and the uses of the past. Through a series of 12 papers written especially for the colloquium and through ancillary readings, participating faculty members concerned themselves with the following series of related topics:

1) the phenomenology of everyday life and the relation of daily, commonsense categories to the critical categories of historical and sociological study; 2) the problem of continuity and discontinuity in changes of basic concepts, orientations, or "world views" in intellectual history; 3) metaphor as subject and as substance of critical thinking; and 4) realism or verisimilitude in art and science -- the extent to which the basic, orienting concepts of disciplines and artistic professions must correspond to views of reality developed in the course of historical life.

As a result of these discussions new subjects will be added to the Seminar's offerings and old ones revised.

This year, in connection with one of its subjects, the Seminar offered a series of public lectures on the topic Darwinism and Culture. The series was planned so that each lecture would speak both to students registered in the subject and to the interests of a general public; as a result, in addition to their cumulative effect, the lectures might be attended individually. The purpose of the series was to understand Darwinism as an intellectual event both in its contribution to the foundations of modern biological science and in its general influence on the climate of intellectual and social opinion. The aim, in part, was also to show how Darwinism emerged from what one writer has called "the common intellectual context" of the 19th century. The six sessions dealt with: 1) an overview of the Darwinian argument, 2) the effect of Darwinism on the world view of Darwin's immediate generation, 3) the relevance -- or lack of it -- of genetical hypotheses of a Darwinian cast to human genetical research, 4) the effect of Darwin's arguments on theories of social evolution during the 19th century, 5) the roots of ecology in Darwin's notion of a "natural economy," and 6) the application of Darwinian paradigms concerning

"the survival of the fittest" when writing the history of ideas. The list of speakers and announced topics ran as follows:

"The Argument of Darwin's Origin and its Contemporary Reception" -- Everett Mendelsohn, Chairman, Department of the History of Science, Harvard University.

"The Concept of Progress in Organic Evolution" -- John Greene, Department of History, University of Connecticut Graduate School.

"The Evolution of Natural Communities: Darwinism and Ecology" -- Jared M. Diamond, Professor of Physiology, University of California School of Medicine.

"The Evolution of Human Communities: Darwinism and the Study of Culture" -- George Stocking, Jr., Morris Fishbein Professor, Center for the Study of History of Science and Medicine, University of Chicago.

"Darwinism and the Social Propensities of Man" -- Richard Lewontin, Agassiz Professor of Zoology, Harvard University.

"Darwinism, Intellectual History and the Growth of Knowledge" -- Professor Marjorie Grene, Department of Philosophy, University of California at Davis.

The series was exceptionally well attended. We hope it will prove a model for subsequent efforts. A second series currently is being planned for the subject Ideas of Progress.

ALVIN C. KIBEL

CROSSROADS IN WESTERN TRADITION

Crossroads is an interdisciplinary program of the Department of Humanities, offering undergraduate subjects in major texts and issues in the intellectual and cultural traditions of the West.

In 1976-77 we offered six subjects in which there were 176 students enrolled. These subjects and their instructors included:

The Bible and Western Tradition	Robert Jones (French and Humanities) Peter Donaldson (Literature)
The Greeks	William Watson (History)
The Renaissance in the North and the Reformation	Richard Douglas (History)
The Enlightenment	Ruth Perry (Literature)
Romanticism in Literature and Painting	Murray Biggs (Literature) Judith Wechsler (Art History)
The Moderns	Murray Biggs (Literature)

For next year we are adding a subject in major medieval texts taught by Professor William Watson. Professor Arthur Steinberg (Archaeology) will teach a subject entitled The Greeks and revised versions of the Romanticism subject and the Modern subject will be taught by Professors Travis Merritt and Robert Jones, respectively.

The program has sponsored several public lecture series in its three-year history, but this year we used support from the I. Austin Kelly fund to sponsor lecturers to come into the classroom itself, including talks by the painter Flora Natapoff, a discussion of Greek Art by Professor Emeritus William C. Greene, and Professor Otis Fellows of Columbia University, who spoke on the Enlightenment.

The staff is engaged in ongoing discussions aimed at clarifying the aims and prospects of general education and related enterprises, and we are planning both a lecture series and a faculty seminar on topics related to these questions (possibly centering upon the idea of tradition) for next year.

PETER DONALDSON

COURSE XXI

Like the preceding year, 1976-77 was for Course XXI a time mostly of planning, uncertainty, and anticipation. While a number of things have been done to improve the procedural functioning of the office and to enhance the quality of the various degree options, there are a number of important policy issues which have of necessity remained unresolved, and a couple of educational initiatives whose implementation has been deferred.

The Joint Major

It is most sharply disappointing to the directors that another year has passed without definitive action on a new degree program to replace the existing joint programs XXI-A (Humanities and Engineering) and XXI-B, 1 (Humanities and Science). The defects internal to these forms of the XXI major, and the external influences which contributed to their declining popularity, remain substantially unchanged. In October 1976, after two years of extensive consultation and planning (described in earlier annual reports), Professors Travis R. Merritt and Louis R. Bucciarelli brought to Department Head Bruce Mazlish and the Policy Committee of the Department of Humanities, as well as to the Dean of the School of Humanities and Social Science, a detailed "Proposal for Action on Joint Degree Programs in Humanities and Engineering/Science." Although this document was favorably received in several quarters, and although there are available for next year academic subjects expressly suited for the Core Rotation of the proposed program and faculty members willing to act as tutor/advisors within it, the proponents were urged to defer implementation pending crystallization of plans by the new chaired professors in the School of Humanities and Social Science, headed by Professor Elting Morison. Professors Merritt and Bucciarelli met with the Morison group in November, and there was a useful preliminary discussion of shared objectives and differing means, but since then working contact between the two enterprises has been informal and scant. It is expected that a firm proposal from the Morison group will soon be forthcoming, so that it can be discussed with an eye to constructive collaboration. In any case, Professors Merritt and Bucciarelli will move early in fall term to implement their proposal effective September 1978.

The Full Major

As for the several full major programs offered in XXI-B, (Humanities and Science) it can be said that these are at present stronger and more attractive to students than their XXI-A and XXI-B, 1 counterparts, but the situation, of course, varies in each of the fields represented: Anthropology/Archaeology, History, Literature, Music, and Writing.

Special Interdisciplinary Majors

There are two interdisciplinary areas of study available for majoring only in the joint (XXI-A, XXI-B, 1) mode. Neither of them has yet achieved the internal coherence and attractiveness to M.I.T. students which were envisioned at the time of their launching in 1974.

American Studies: Although a few students have undertaken this major and made a good thing of it, American Studies is still a very loosely organized program with a lot of potential and too little concerted faculty consciousness. Remedy for its defects can be found only through direct and sustained consultation among all concerned teachers whose interests bear on American affairs. This must include a central group from several of the Sections of the Department of Humanities, but it must extend as well to faculty from other departments and schools. Recent hirings have strengthened the Department's hand somewhat, and Professor Leo Marx's willingness to participate in building a sound American Studies program is especially encouraging. Professor Arthur Kaledin's return from leave next year will provide specifically useful initiative in American history and letters. It should be possible in fall term to begin to move purposefully.

Russian Studies: This program has yet to enroll a single major. The participatory enthusiasm of Professor Krystyna Pomorska has not been matched by other faculty members. It may well be advisable, next year, to recommend that Russian Studies be dropped as a major option until it acquires more curricular mass. The program should probably be retained by the Department, however, as an opportunity for concentrators.

Miscellaneous

The Course XXI Senior Humanities Seminar (21.901) for XXI-A and XXI-B, 1 majors was ably led this year by Professor Kenneth Manning of the Technology Studies faculty.

In April the Course XXI office organized a Humanities Open House to display the Department's wares and provide interested undergraduates with information and advice on subjects, concentrations, majors, and careers. It was the most successful such venture in recent memory.

The I. Austin Kelly Prize competition, now in its third year, enjoyed a particularly strong group of entries. The winners were Cynthia Koelker, Class of 1977 and John Palys, Class of 1978.

The Humanities Students Association, relatively inactive this year, has already begun to make plans, in collaboration with several faculty members, for a series of social and intellectual events for 1977-78.

Course XXI notes with pride the achievement of James E. Adams, Class of 1977, a Literature major and earlier winner of the Kelly Prize, who received a Rhodes Scholarship for study at Oxford. He is the first M.I.T. student to be so honored in a dozen years, and the first ever from this Department.

TRAVIS R. MERRITT

Department of Linguistics and Philosophy

The year 1976-77 marked the first year of operation of this new Department formed by the merger of the linguistics section of the former Department of Foreign Literatures and Linguistics with the former Department of Philosophy. This merger has established at M.I.T. a distinctive center for the study of language and related cognitive areas. Under the new administrative arrangement, linguists and philosophers retain a fair amount of autonomy, but advantage is taken of the shared intellectual and educational interests they have built over the years. Interaction among students and faculty members has been facilitated and promises to be most productive.

The merger has led to a number of curricular innovations. Several new subjects of interest to both groups have been introduced and some will be taught jointly by philosophers and linguists. In addition, some changes have been made in the curriculum of the Ph.D. program in linguistics. The new department also has sponsored the M.I.T. Philosophy and Linguistics Colloquium, a series of invited lectures, open to the M.I.T. community, by philosophers, linguists, and psychologists on topics about language.

However, the major educational innovation has been the institution of a new undergraduate major called Language and Mind. This is a course designed for undergraduates interested in areas common to philosophy, linguistics, and cognitive psychology, such as the nature of language, the structure of innate knowledge, the relation between logic and language, etc.

RESEARCH

As might be expected, the departmental reorganization has not yet had a pronounced effect on the research carried out by members of the Department since most of their work this year was begun well before the organizational changes. Among the highlights in this area the following might be mentioned.

The insight basic to Professor Joan Bresnan's exploration has been the explicit recognition of the autonomy of semantics and syntax by postulating separate sets of primitives for the two domains. Syntactic representations are composed of structural primitives (categories, dominance, precedence), while semantic representations are composed of lexical and functional primitives (predicates, subjects, objects, complements). In such a model, the fundamental problem in computing semantic interpretations is that of associating the semantic predicates for words with the syntactic forms in which the words appear in sentences. Professor Bresnan's solution involves the construction of lexical functional structures for verbs, which combine the logical argument structures of semantic predicates with grammatical functions defined on surface structures in such a way as to provide direct mapping between the argument positions of the predicates and the syntactic contexts in which words actually occur. An initial report of this work will appear in M. Halle, J. Bresnan, G.A. Miller, eds., Linguistic Theory and Psychological Reality (M.I.T. Press - in production).

Institute Professor Noam Chomsky's research has concentrated on studying the effects of a radical restructuring of the descriptive devices of linguistics. In particular, he has attempted to eliminate the great richness and variety of transformational devices postulated in earlier work in favor of an extremely limited system of surface filters, and has found that this impoverishment of the available descriptive devices does not affect the system's ability to reflect adequately

the relevant linguistic data. In fact, the limited system provides explanations for a number of well-known, but hitherto puzzling cross-linguistic uniformities such as the restrictions on the questioning of sentential subjects in widely differing languages, and certain quite intricate properties of infinitival constructions. Moreover, many specific properties of transformational rules can be explained on the basis of independently motivated principles of anaphora, through the medium of a specially developed "theory of traces," and on the basis of independent principles governing logical form. The results of these investigations will be published in a number of papers now in progress. See, in particular, "Filters and Control," Linguistic Inquiry, 8 (with H. Lasnik) and "On Wh-Movement," Formal Syntax, A. Akmajian, P. Culicover, T. Wasow, eds., Academic Press.

Professor Ned Block's work on functionalism will appear as a major article in the next volume of the Minnesota Studies in the Philosophy of Science.

Professor George Boolos has developed a new approach to modal logic which involves the application of modal logic to proof theory. His work constitutes a contribution to both fields and will appear in a book Provability, Self-reference, and Modal Logic that will be published by Cambridge University Press.

Professor Paul Horwich worked on, among other topics, philosophical problems which derive from the General Theory of Relativity. These results will appear in three articles, "Convention-
alism and the Epistemology of Geometry," "On Transforming the Metric of Time," and "On the Existence of Time, Space, and Space-Time."

Professor Irving Singer's work on aesthetics resulted in a number of published papers and in a book Mozart and Beethoven: The Concept of Love in Their Operas, to be published by the Johns Hopkins University Press.

Professor Judith Thomson has completed a phase of her work on the theory of action which will be published in a book entitled Acts and Events, to be published by Cornell University Press.

Members of the Department participated actively in two workshops that submitted their final reports during this academic year. Professors Bresnan, Morris Halle, and George Miller (Visiting Professor from Rockefeller University) took leading parts in a series of workshops on problems of languages and cognition that met between January 1975 and May 1977. These workshops were organized with a special grant from the American Telephone and Telegraph Company, as part of the centennial celebration of the invention of the telephone. Papers that grew out of these workshops will appear in the M. Halle, J. Bresnan, G. Miller, eds., mentioned above.

Professors Chomsky and Halle and Dr. Mary-Louise Kean took part in a workshop on the biological foundations of language. This workshop, which met at M. I. T. in 1975 and 1976, attempted to survey and rethink much of the accumulated information on the biological aspects of language from the perspectives of the latest advances in linguistic theory with the aim of laying the foundations for a comprehensive program of research in this area. The final mimeographed report of this workshop was published early in 1977. This workshop was supported in part by a grant from the Alfred P. Sloan Foundation. A new grant of modest size has just been approved by the Sloan Foundation to be used for further explorations in this domain.

Professor Thomson gave lectures at the City University of New York Bicentennial Symposium on Philosophy and at the American Philosophical Association Symposium on Property Rights. Professor Singer also was a symposiast at the former symposium.

Honors

Two members of the Department, Professors David Perlmutter and John R. Ross, were awarded Guggenheim Fellowships for the academic year 1977-78. Professors Horwich and James Kostman received Old Dominion Fellowships for fall term, 1976, and Professor Barbara Herman received an Old Dominion Fellowship for spring term, 1977.

FACULTY

Effective July 1, 1977, the department will be headed by Professor Samuel Jay Keyser, who has served as head of the linguistics program at the University of Massachusetts, Amherst.

Professor Block was promoted to Associate Professor (effective July 1, 1977) and awarded tenure (effective July 1, 1978).

Joshua Cohen, who is completing his work on a Ph. D. in philosophy at Harvard, was appointed as an assistant professor in the Department. Professor Cohen, whose specialities are political philosophy and ethics, will have teaching responsibilities both in this Department and in the Department of Political Science.

George Miller, Professor of Psychology at Rockefeller University, held an appointment as Visiting Professor in this Department and in the Department of Psychology. Professor Miller's appointment has been renewed for 1977-78.

Professor Kenneth Hale was on leave at the University of Arizona during the entire academic year. Professor Horwich was on leave during fall term. Professor Paul Kiparsky was on leave during the entire year at the University of Poona, India. Professor Kostman was Visiting Assistant Professor at the University of California at Berkeley during spring term, and Professor Judith Thomson was Visiting Professor in the Department of Philosophy at the University of Pittsburgh in the fall.

Professors Perlmutter, Izchak Miller, and Miles Morgan will leave the Institute at the end of this academic year.

MORRIS HALLE

Department of Political Science

Among the important developments and events within the Department this past year have been the planning for a new undergraduate program in public policy under a grant from the Alfred P. Sloan Foundation, the inauguration of an expanded departmental Master's program, a spurt in faculty involvement in public affairs in Washington, and the untimely death of Professor Jeffrey Pressman.

Undergraduate Program

The expansion of field opportunities for undergraduates and planning for a new undergraduate program for 1977-78 were two of the most important developments in the undergraduate program this past year.

The Department continues to seek opportunities to involve undergraduates in some kind of field experience in public affairs or in research. Under the leadership of Professor Martha Weinberg, the Department's summer internship program has been substantially expanded. For summer, 1977, 12 students were placed in government agencies in Washington and an additional 14 students in state and local government, as against a total of seven placements in summer, 1976. The expansion of this program was made possible through collaboration with the Department of Urban Studies and Planning, UROP, and the Work-Study program, and the support of the Department faculty. The summer internship program is an important supplement to the still larger internship program run by the Department in collaboration with Urban Studies during the regular academic year. Both programs provide opportunities for students all over the Institute, not only from the Department of Political Science.

Faculty research on the 1976 elections also provided a number of students with opportunities to work with faculty members in field situations. Professors Weinberg and Jeffrey Pressman, and colleagues from Yale and Dartmouth, engaged in a study of the 1976 Democratic and Republican national conventions. The convention study team included approximately 20 undergraduates from M.I.T., Dartmouth, and Yale. The study was made possible by grants from the Ford Foundation and from the National Endowment for the Humanities. Another opportunity was provided to a group of students working with Edwin Diamond to prepare a videotape documentary of the presidential campaign under a grant from the Sloan Foundation and from public television. Mr. Diamond also led a group of students in the News Study Group to the primaries and to the conventions as part of his research project on the role of the press in the 1976 presidential primary campaign.

In fall, 1977, the Department will initiate a new undergraduate program in public policy as a variant of the present political science major. The new program is intended for students who anticipate public service careers, or who simply seek a better understanding of the policy process and of substantive policy problems. The program should be particularly valuable to students who plan to pursue graduate work in law, health care, public administration, and other fields which involve public policy, and it should also be of value to young scientists and engineers who anticipate an involvement with the public sector.

Starting in fall, 1977, the Department will offer a new group of core subjects in public policy and a seminar on policy implementation. An important feature of the program will be an internship for each student with a state or local public agency or legislator, supplemented by a seminar for the participants. The public policy program is intended not only for departmental majors and double majors, but also for students majoring in other fields who wish to do a humanities concentration in public policy studies. This past year a faculty committee, chaired by Professor Alan Altshuler and functioning under a grant from the Sloan Foundation, has been working on curriculum development for the new program.

A large number of students, both graduates and undergraduates, attended Agenda '76, a series of biweekly seminars on issues in the 1976 election campaign which featured faculty members from the Department as well as a number of guest speakers. The series was organized by Professor Weinberg.

Graduate Program

This past year a number of students have been admitted into an expanded Departmental Master's program in the fields of arms control and defense analysis and in science and public policy. A central objective of this program is to provide research training on public policies leading toward careers in public service. An increased number of students have entered the program this past year, especially in the arms control and defense fields, but it is too soon to assess the program and to determine whether the Department ought to seek a designated degree in this field of study. The program has been under the guidance of Professor Ted Greenwood.

A number of new or revised subjects has been introduced into the curriculum of the graduate program. Among these were a new subject on political economy taught by Professor Suzanne Berger jointly with Professor Michael Piore of the Department of Economics; a subject on the policymaking process by Professor Weinberg; a health policy seminar by Professor Harvey Sapolsky taught jointly with Dr. Stanley Finkelstein, a lecturer in the Department; a subject on US policy toward Southern Africa by Professor Willard Johnson; a restructured seminar on the politics of development and underdevelopment by Professor Wayne Cornelius; and an expansion of the subject on East European politics to include West European Communism by Professor William Griffith.

The Department continues to be faced with a serious problem of finding funding for its graduate students. The Financial Aid Committee of the Department must determine how to equitably allocate its own limited funds between entering students who are not ordinarily eligible for teaching assistantships and most research assistantships, and students who have completed a year of graduate studies but are not yet in a position to seek outside support for doctoral thesis research. There has been a slight relief for the graduate students as a result of a grant to the Department from the Sloan Foundation for the development of our undergraduate public policy program. A number of advanced graduate students will be working in the new program on the preparation of teaching materials and as teaching assistants. Funds from the Ford Foundation to the arms control program also have been important for supporting students in that field of study. Nonetheless, the need continues to be substantially greater than the resources available, and the Department continues to be concerned about its capacity to financially compete with other institutions for the attraction of the best graduate students.

The Department is gratified by the continued success of its graduate students in soliciting financial support from outside the Institute. Among the awards received by graduate students in 1976-77 were grants from the University Consortium for World Order Studies, the Ford Foundation, the Fulbright-Hays Foundation, the Canada Council, the National Science Foundation, the Danforth Foundation, the Earhart Foundation, the Scripps Howard Foundation, and from the governments of Canada, France, Germany, Iran, Malaysia, and Pakistan.

In spite of the stringent job market, students completing the Doctoral degree continued to do well. This past year graduates found teaching appointments at the University of California at Berkeley, the University of Pennsylvania, Brandeis University, the University of Washington, Wellesley College, Clark University, and the University of Islamabad. Two students took research positions with the Library of Congress and with the Senate Armed Services Committee, while two students accepted postdoctoral awards.

Publications

Comparative analyses and studies of politics in the developing countries and within Europe continue as a major focus for many members of the Department. This year the following studies appeared: a volume edited and coauthored by Professor Cornelius, Metropolitan Problems and Governmental Response in Latin America; two volumes on Africa by Professor Robert Rotberg, Black Heart: Gore Browne and the Politics of Multiracial Zambia, and The Black Homelands of South Africa; the last of a four-volume series coedited by Professor Myron Weiner from his project on electoral politics in India, Electoral Politics in the Indian States: The Impact of Modernization; several articles by Professor Lucian Pye on recent changes in Chinese political leadership; a study prepared by Professor Johnson on American investment in South Africa presented to the US House of Representatives Subcommittee on African Affairs; and a monograph by Professor Nazli Choucri, The New Migration in the Middle East.

Studies prepared by three faculty members for the Rockefeller Commission on Critical Choices for Americans have appeared. Two papers prepared by Professor Berger, "France: The Dilemmas of Alliance," and "Italy: On the Brink or on the Verge?," have appeared in David

Landes, ed., The United States and Western Europe. Professor Weiner's study, "Critical Choices for India and America," appeared in Donald C. Hellman, ed., Southern Asia: The Politics of Poverty and Peace. And Professor Griffith has edited one of the volumes for the Commission, The Soviet Empire: Expansion and Detente.

Professor Douglas Hibbs has published several articles on industrial conflict and on political parties and macroeconomic policy in advanced industrial societies.

Members of the Department have recently published a number of studies that focus on contemporary issues in public policy. In the field of nuclear proliferation, Professors Greenwood, Eugene Skolnikoff, and George Rathjens, have contributed papers to a volume on International Arrangements for Nuclear Fuel Reprocessing, edited by Chayes and Lewis. Professor Skolnikoff also has written on science policies and on global food and health policies. Professor Sapolsky has published papers dealing with American health care policy. Professor Altshuler has written several articles on urban transportation and is presently completing a book on the politics and problems of urban transportation in the United States. Professor Michael Lipsky is coauthor of a book on Commission Politics: The Processing of Racial Crisis in America.

Professor Hayward Alker has published or has in press several papers on world modeling, including "Limits to Growth," a study of collective insecurity, a paper on global modeling alternatives, and a study of constraints and opportunities for regional development. Professor Lloyd Etheredge's lively monograph, The Case of the Unreturned Cafeteria Trays: Psychological Theory and Public Policy, was published by the American Political Science Association in a new series of monographs for undergraduate instruction.

Finally, elections in the United States and in India generated a number of papers, both published and ephemeral, by Professors Weiner and Dean Burnham. Professor Burnham is also at work editing a volume tentatively entitled Politics and Policy in America for the M. I. T. Press, as a memorial to Professor Pressman.

RESEARCH AND TEACHING

Interdepartmental and interdisciplinary research and teaching involve many members of the Department. Professors Skolnikoff and Weiner continue to serve on the advisory board of the International Nutrition Planning Program, a teaching and research program jointly run by the Department of Nutrition and Food Science and the Center for International Studies. Professor Weiner is the director of a research program on migration and development which involves members of the Department of Economics and the Boston University African Studies Program. The program runs a fortnightly faculty-student research seminar that attracts guest speakers from around the country. Professor Weinberg has been teaching in the new Master's program on Technology and Public Policy in the School of Engineering. The Department also continues its close links with the program in Technology Studies in the School of Humanities and Social Science, with Professor Langdon Winner serving in his dual capacity as assistant professor in both Political Science and Technology Studies, and with Professor Joel Yellin in Technology Studies who has been teaching an undergraduate subject in political science on Value, Choice and Risk in Modern Technology which explores some of the major social effects on 20th-century technology. Professors Choucri and Berger have worked in the M. I. T. Technology Adaptation Program in their new program on small-scale industrial development in Egypt. Professor Choucri is the Associate Director of the Technology Adaptation Program.

Other faculty members also have served on interdepartmental or Institute-wide committees. Professor Altshuler has been chairman of the M. I. T. Advisory Committee on the Secondary Technical Education Project. This involves the development of a magnet school in East Boston as part of Judge W. Arthur Garrity's order for integration of the Boston school system.

Professor Altshuler is also the principal investigator in a multidepartmental, multidisciplinary research project entitled "New Perspectives in Urban Transportation," funded by the US Department of Transportation. Professor George Rathjens served on the M. I. T. Ad Hoc Committee on International Institutional Commitments. Professor Greenwood served on the steering committee of the Energy Laboratory and the oversight committee of the Technology and Public Policy Program. Professor Johnson served on the advisory committee to the Office of Minority Education. Professor Lucian Pye has stepped down as chairman of the Faculty Club but continues on its advisory committee.

Much of the research by faculty members, especially in international subjects, is conducted with the cooperation and often under the aegis of the Center for International Studies. The Center plays a particularly important role in helping to raise research funds and in administering many research projects.

FACULTY

Public Service and Professional Activities

The change in administration in Washington increased the involvement of members of the Department in public affairs during the past year. Professors Skolnikoff and Greenwood have been working with Professor Frank Press, former Head of the Department of Earth and Planetary Sciences and the new Director of the Office of Science and Technology Policy in the Executive Office of the President. Professor William Kaufmann, who served as a consultant to Secretary of Defense Donald Rumsfeld continues as a consultant to the new Defense Secretary Harold Brown. In January 1977, Secretary Rumsfeld awarded the Department of Defense Distinguished Public Service Medal to Professor Kaufmann.

Professors Johnson, Rotberg, Griffith, Pye, and Weiner all served as consultants to the Department of State; and Professor Cornelius has been working with members of the White House staff on problems of illegal Mexican migration to the US. Several papers prepared by Professor Cornelius on this controversial issue have received wide circulation, including an article on the Op-Ed page of the New York Times.

In the field of local government, Professor Altshuler has been working with the Metropolitan Council of Minneapolis-St. Paul, Minnesota on a prospectus for transportation planning, and Professor Weinberg has served as an advisor to Mayor Kevin White on changes in the Boston City Charter and on personnel recruitment for the city.

Professor Berger has been appointed chairman of the Social Science Research Council (SSRC)-American Council of Learned Societies Joint Committee on Western Europe, and Professor Hibbs has joined the new SSRC Committee on Longitudinal Methodology and the Political Science Program Board of the National Science Foundation. Professor Alker has completed his term as a member of the governing council of the American Political Science Association. He is serving as a member of the International Science Association program planning committee for its 1979 meeting in Moscow. Professor Cornelius served as program chairman for the national meeting of the Latin American Studies Association and the African Studies Association.

Professor Pye continues as Vice Chairman of the National Committee on US-Chinese Relations, and as a director of the Council on Foreign Relations, the Asia Foundation, and the World Affairs Council of Boston. Professor Rathjens continues to serve on the National Academy of Sciences Pugwash Conferences, and on the Committee on International Studies of Arms Control of the American Academy of Arts and Sciences. Professor Sapolsky serves on the Science and Public Policy Commission of the American Association for the Advancement of Science.

Personnel

The tragic and untimely death of Professor Jeffrey Pressman came as a terrible shock to both faculty and students. Though Professor Pressman came to M. I. T. only four years ago, he quickly established himself as a leading member of the profession, and as a central figure in the Department's teaching and research program in the field of American politics and policies. His two books on the politics of the implementation process and his recent studies of convention politics were widely received as significant contributions to our understanding of American politics. Professor Pressman played a particularly important role in galvanizing the Department's undergraduate program. His death was bereaved by many friends and colleagues and by an outpouring of his students at a memorial service in Kresge Auditorium. In memory of Professor Pressman, the Department is planning to create an annual Institute prize for the best undergraduate paper in the field of American government and politics.

Five Department members were on research leave this past year -- Professors Rotberg, Choucri, Ithiel de Sola Pool, Lincoln Bloomfield, and Dr. Louis Menand. Dr. Kas Kalba, a specialist in the field of communications research, joined the Department for the year as a partial replacement for Professor Pool. Another partial replacement for Professor Pool was Professor Herbert Hyman of the Department of Sociology of Wesleyan University. Replacing Professor Choucri for one semester was Professor Edward Azar of the Department of Political Science of the University of North Carolina.

Professor Hibbs will be spending the 1977-78 academic year as a fellow at the Center for Advanced Study in the Behavioral Sciences at Stanford. Professor Greenwood will be on leave to work with the Director of the Office of Science and Technology Policy in the Executive Office of the President. Thomas Wolf, a graduate student serving as a teaching assistant for Professor Pressman and who received an Institute award for excellence in undergraduate teaching, has been appointed as an instructor for one semester. Donald Morrison, formerly on the faculty of Ibadan University, has been appointed for a year to replace Professor Hibbs.

Two new faculty members will join the Department next year. Joshua Cohen, a recent graduate from Harvard, has been appointed as an assistant professor in the Departments of Political Science and Linguistics and Philosophy to teach courses in political theory and political philosophy. Deborah Stone has been appointed as an assistant professor to teach in the new undergraduate program in public policy. She has been teaching at Duke University for the past two years.

Professor Sapolsky was promoted to Full Professor, Professor Berger completed her term as Associate Chairman of the Faculty, and Professor Weiner completed his term as Head of the Department of Political Science. Professor Altshuler has been appointed new Department Head.

MYRON WEINER

Department of Psychology

The end of the academic year finds us as actively engaged in research and teaching as in previous years but deeply saddened by the loss at mid-year of Hans-Lukas Teuber, who not only founded the Department but headed it, in the strongest sense, until his death. The shock of this loss has its repercussions in practically all the functions of the Department, and it weighs heavily in our considerations for the future.

As Luke Teuber was fond of pointing out, this Department has been shaped along unorthodox lines. Anticipating important advances in certain of the brain sciences, at that time rather remotely tied to the study of behavior, he boldly brought together a highly selected faculty commanding a set of disciplines bridging the fields of brain and behavior. Their interests ranged from neuroanatomy to neurophysiology and the effects of brain pathologies; through visual processes, the study of movement, and of their coordination in sequences of behavior; to processes of thinking, memory, and of the development of language.

The viability of this combination of disciplines and the talents assembled to further our knowledge in these areas has, by now, been demonstrated in many ways, including the visibility, on the national and international levels, of our faculty and staff, as well as former students who have moved on to other institutions; by participation in a multiplicity of research and educational projects within and across departmental lines; and by the carrying out of teaching responsibilities at both the graduate and undergraduate levels. A particularly welcome note of approval has come in the form of a five-year award of Federal support for our training program. We are one of the few remaining programs to be so funded.

The problem for the future is the maintenance of our unity of purpose under the pressures for increased participation of our faculty in many scientific and educational endeavors, both inside and outside the Institute, and at a time when the Federal sources for research funding appear to be drying up.

RESEARCH

The laboratories of the Department are organized into a set of allied fiefdoms, each presided over by a member of the faculty who, in addition to conducting the affairs of the laboratory, is responsible for the individuals working within his or her domain. They normally include students, both graduate and undergraduate, postdoctoral fellows, research associates, technicians, and visitors. In addition, these individual laboratories share common facilities such as the library, shop, animal quarters, and administrative services. Communication and cooperation among the separate laboratories is maintained at a level commensurate with their usefulness. The closest links are naturally between those laboratories and individuals whose immediate research interests overlap. Despite the diversity of research, these links form a continuous chain tying together all of our researches ranging from neuroanatomy to the role of syntax in speech recognition. An overarching unity is fostered by a common interest in the workings of the brain and mind. This interest has provided an important shared theme which comes to a focus in our studies of human patients with brain pathologies. Here we keenly feel the loss of Hans-Lukas Teuber, who formerly directed this effort. His associates, Suzanne Corkin and Thomas Twitchell, and their collaborators are working very hard to maintain the program in this area, and the faculty are strongly supporting them.

Funding of the laboratories has paralleled their organization: each laboratory has been funded by grants awarded to the responsible faculty member. But in addition we have been fortunate in attracting support for projects incorporating the work of several of these laboratories and, for some purposes, the entire Department. These "block grants" have been enormously useful in enhancing the cooperation among our various laboratories, for providing seed money for developing new ideas for which grant support is hard to come by in the present funding situation, and for startup support for new faculty. However, over the past few years, the amount of such block funds available to us has steadily declined despite an increase in total research funding to the Department maintained through an increase in grant funding to individual faculty. We should remedy this situation in the future in order to retain the flexibility in research direction that we have enjoyed in the past.

The more than 100 research publications produced during the past year attest to the continued health of our research effort, as do the 79 invitations to our faculty members to participate in national and international conferences and to address interested groups at other institutions.

TEACHING

Twenty-one graduate subjects were offered and attended by 168 graduate students, including a good number from other departments and several from neighboring institutions. Seventeen undergraduate subjects were listed by this Department despite the fact that we do not offer an undergraduate degree. From the four undergraduate classes, including the 1977 graduating class, we have 254 students registered as concentrators in our field. Professor Teuber's famous introductory subject, 9.00 Introduction to Behavioral and Brain Sciences, was offered for the last time in the fall. As usual, it drew more than 300 students. It has been the most popular undergraduate elective subject at the Institute.

Undergraduate enrollment came to 738, a reduction in enrollment from the previous year which follows the trend set in that year. Two reasons account for these reductions. First, the elimination of several of our subjects from the Humanities Concentration Requirement list. Second, the absence of Dr. Teuber, who was scheduled to teach a large undergraduate subject. We are under no illusions about replacing a teacher of Dr. Teuber's brilliance. Instead, we must reconsider and revise the structure of our undergraduate offerings.

The colloquium program continues its popularity not only among our students but also among fellow professionals from other local institutions. In sponsoring these lectures by visiting psychologists and other researchers from the neural and behavioral sciences, we serve the community as well as ourselves.

FACULTY

During the year we were greatly pleased to be able to add Professor Mary Potter to our tenured faculty as well as to promote Professor Susan Carey to the rank of Associate Professor. With mixed emotions, Professor Held assumed the role of Acting Head and will become Head as of July 1, 1977. Among our visitors was Malcolm Piercy, University Lecturer at the University of Cambridge, who literally sailed across the Atlantic to spend several months with us helping in the teaching of the neuropsychology subject directed by Drs. Corkin and Twitchell. Several score of other psychologists and brain scientists, 21 from abroad, came for shorter visits ranging from one to several days, often in conjunction with a colloquium presentation, of which we had 43 in the course of the year. In addition, we have had 12 postdoctoral fellows on the premises, including four from foreign countries, for periods ranging from a year to several years. These fellows, generally supported by awards from other institutions, chiefly the National Institutes of Health, make important contributions to our program, and we gain much from their participation in the research and educational efforts of the Department.

Our own faculty presented invited lectures to groups at other institutions on 79 occasions, in addition to their usual participation, often in collaboration with students, in shorter oral presentations at professional meetings. Notable among recognitions accorded to them were Professor Teuber's keynote address to the International Congress of Psychology meetings in Paris; Professor Walle Nauta's Distinguished Lecturer Visit to the University of Southern California; Professor Stephan Chorover's address to the American Psychological Association in Washington, DC; Professor Merrill Garrett's service to the Max Planck Society's Psycholinguistics meeting at Nijmegen; Professor Held's lecture delivered at the International Congress in Paris; Professor Potter's presentation to the LOVE (Lake Ontario Vision Experimenters)

Conference meeting at Niagara Falls in Canada; Professor Gerald Schneider's lecture to the European Federation of Child Neurology Societies at Braunlage, West Germany; Professors Carey and Potter's participation in the Boston University Language Development Conference; Professors Emilio Bizzi, Ann M. Lackner-Graybiel, and Peter Schiller's presentations at the Dahlem Conference on Vision at Berlin, Germany; and Professors Held, Schiller, Alan Hein, and Whitman Richards' lectures at the dedication of the new School of Optometry at Houston, Texas. Professor Held received an Honorary Doctorate from the New England College of Optometry in Boston.

THE FUTURE

The bell has tolled for one of us during a period of the most vigorous activity in which our group has engaged up to this time. It is a moment for reassessing our status and direction.

As the Press Committee Report on the Status of Research at the Institute has suggested, this Department is rather like a cross between a research center and a more typical academic department. We award graduate degrees and teach undergraduate subjects but do not have a formal undergraduate course leading to a degree. The size of our research related budget dwarfs that for educational purposes yet our faculty teach, in addition to fulfilling their obligations within their Department, in many courses jointly with faculty of other departments and serve on a wide variety of education related committees within the Institute. We are closely tied not only by teaching but also by consultative and research interests to several other major foci of work within the Institute.

This Department contains the largest single faculty of brain scientists among more than a dozen identifiable groups within the Institute. In any plan to formalize teaching and research in this area of ever-increasing interests -- it has been called the last frontier of science -- these faculty will inevitably play an important role. On the other hand, we have a significant number of cognitive scientists on our faculty engaged in another salient of this frontier -- one in which mind examines itself. They already play a role in the planned and partially funded efforts of the Program for the Cognitive Sciences. Two of our faculty have been engaged in work with the Division for Study and Research in Education. At least one of our faculty has closely collaborated in an aspect of the work of the Artificial Intelligence Laboratory. Others of us have been engaged in collaboration with the Laboratory of Neuroendocrine Regulation in the Department of Nutrition and Food Science, with the Neurosciences Research Program, the Division of Health Sciences and Technology, with the Speech group of the Research Laboratory for Electronics, with ongoing rehabilitation research in the Department of Mechanical Engineering, with the research of the Man-Vehicle Laboratory of the Department of Aeronautics and Astronautics, and with several other entities within the Institute.

The Institute-wide ties of this Department, enumerated above, make clear that its faculty members are engaged in a surprisingly large variety of activities often dealing with the applied sciences and skills. On reflection, one may conclude that these engagements by invitation stem from the strength in fundamental research and knowledge demonstrated by the faculty and staff of this Department and made possible by its structure and mode of operation. Yet the pressures for participation in other endeavors subject us to potential fragmentation. Balance between these centrifugal tendencies and those conducive to unity has been a perennial problem and remains so.

In the wake of the loss of Hans-Lukas Teuber, the Institute administration has been very supportive of the Department both in word and deed, and we are most appreciative. Moreover, we take this support as a token that we have been doing something right. If we are to continue doing so,

our first priority must be to compensate for what we have lost, to consolidate our gains, and to increase our basic strength in research. Just as the original goals of the Department anticipated the developments of the past decade, our new aims must do so for the next. We shall seek the kind of support that will enable us to move ahead, and it would be most appropriate to have it in the form of a memorial to Luke Teuber.

RICHARD HELD

Sloan School of Management

The Sloan School's teaching, research, and other professional activities have continued to play an important role in meeting society's increased needs for good managers and good management ideas.

The School has been and continues to be a pioneer in developing modern managerial education programs. It has succeeded in attracting and building an outstanding faculty in many important management areas and is a key resource both for research and service to the profession, industry, and the nation. Although relatively young, the School has been a leading educator of key professional managers and its high standards of excellence and achievement have been reflected in high national and international rankings.

The School, in sum, continues in its commitment to developing management programs and ideas which can help train managers whose actions will make a difference to the world.

The task for the future is to build on and extend the School's strengths and to continue to seek the advancement of our understanding of the key management issues which organization and institution builders and shapers have come increasingly to recognize as vital in addressing some of the most troublesome questions of our times.

TEACHING PROGRAMS

Undergraduate Program

Enrollment in the undergraduate degree program in the 1976-77 academic year was a bit lower than the 120 level of the preceding year, but a larger number of out-of-course students, majoring in science, engineering, and other courses, continued to elect management subjects. The number of students earning an undergraduate degree in management concurrently with a second M. I. T. degree also has continued to increase in recent years. These trends reflect growing awareness among M. I. T. students of the need for management skills for working effectively in organizations and in administering affairs in an increasingly complex society.

The Undergraduate Student Advisory Council took responsibility for organizing the School's Open House activities and the annual reception for incoming sophomores. Council representatives also participated in a School review of policies concerning admission of undergraduate majors and non-majors to the School's graduate programs and a modified policy emerging from these efforts will be announced in the coming year.

Professor Peter P. Chen served once again as coordinator for the Sloan School in M. I. T.'s Undergraduate Research Opportunities Program. Senior Lecturer Stanley M. Jacks and Administrative Assistant Esther Merrill continued to serve respectively as chairman and

program coordinator of the undergraduate program and have agreed to serve in these capacities in the coming year. They and our Undergraduate Program Committee members and counselors, Professors Chen, Thomas J. Allen, Roy E. Marsten, Jeffrey A. Meldman, James M. Lyneis, and Arnold I. Barnett, have continued to work on reviewing the undergraduate program and to give effective individual counseling to undergraduates in the face of many other calls on their professional time.

Graduate Program

In 1976-77 the School continued to offer the accelerated (12-month) and regular (two-year) programs leading to the degree of Master of Science in Management with a 1977 graduating class of 35 and 138 respectively.

The School's experience with both programs continues to be excellent. In total, applications for the Master's programs in 1977 reached an all-time high of 1,216, with an increase over the prior year of approximately 35 percent. This appears to be one of the largest increases in any of the major schools. The number of applications from women increased by 27 percent over 1976, to a total of 222, or 18 percent of all received. The School experienced a growth of 21 percent in the number of minority applicants (80 in total this year). The previously increased efforts to recruit more minority and women applicants have helped achieve this advance, and the School will continue to recruit high-quality applicants.

The programs are now widely recognized as unusually high in quality. We also have been able to begin to muster the administrative support (for admissions and placement) that a high-quality professional school requires and we are planning for still further improved support services here as well as improvements in our physical facilities for the near future. Our programs, however, although universally seen as among the best in the country, now are offered at tuition prices well below other top Master's programs and a review of M. I. T.'s tuition policy has been proposed.

The School introduced a number of important program modifications last year. The first change dealt with the manner of organizing thesis research. The individual student working on an individual project under faculty supervision continued in the typical thesis research mode. In addition, last year interested students were encouraged to participate in a thesis research experience which permitted each student to focus on a specific aspect of a commonly agreed-upon substantive focus for the group's research, and to participate in a thesis research seminar in which each student could share experiences and findings with other students and the several supervising faculty members.

The School also organized a two-day field trip visit to a major company for students interested in meeting a number of key managers in that organization, and the School further expanded its administrative seminar series to permit a larger number of invitations to business, government, and labor leaders to the School.

The Master's Program Committee initiated a review of the programs' core subjects and will be seeking to ensure more effective coordination of these modified core materials.

The following data highlight some of the major characteristics of the Classes of 1977 and 1978, including entrants to the two-year Sloan Master's Program (SMP) in September 1975 and 1976 and to the 12-month Accelerated Master's Program (AMP) in June 1976 and 1977.

<u>Characteristic</u>	<u>AMP</u>		<u>SMP</u>	
	<u>1977</u>	<u>1978</u>	<u>1977</u>	<u>1978</u>
Sex: Female/Male	5/31	8/30	32/78	27/87
Age: Median/Range	27/22-39	27/22-38	23/20-44	24/20-40
Married/Single	18/18	16/22	27/84	27/87
Percent with Full-Time Work Experience	100%	100%	55%	54%
From: Countries/States	4/11	5/9	12/22	10/22
Mean Undergraduate Grade Point Average*	4.1	3.8	4.3	4.3
Median Admission Test Score**	628	638	613	628

* On 5.0 scale (excluding some foreign students)

** National average is approximately 460

Preliminary placement data on the Class of 1977 indicate an increase in average starting salary for Master's candidates of about 10 percent, from a mean salary of \$20,000 in 1976 to an estimated \$22,000 for 1977. Sloan is one of three major US business schools which consistently have a higher average starting salary for their graduating classes than other business schools.

There was about a 20 percent increase in the number of organizations recruiting on campus, with more than 115 organizations conducting 2,185 interviews with graduating candidates and 289 interviews with first-year students (for summer employment). In addition to the on-campus recruiting, 462 organizations sent job descriptions by correspondence to the Placement Office for about 680 positions. Consulting firms continued to recruit aggressively this year. Commercial banks continued to dominate recruiting by the financial institutions (a major employer of MBA graduates); however, the investment banks were more visible this year than last. In contrast to the 1975-76 experience when only a few of the accounting firms recruited, all eight of the major public accounting firms recruited at Sloan during 1976-77, primarily for their management services groups. Most notable in this year's recruiting was an increase in the number of manufacturing organizations and the increased range of industries represented. Recruiting by public sector organizations and agencies was less active than last year, due in large part to the change in administration in Washington and resulting reorganizations.

The Ph.D. Program

The primary objective of the Sloan School's doctoral program continues to be the education and training of men and women pursuing careers in either research and teaching or in nonacademic positions requiring advanced research and analytical capabilities.

Our program combines study in the theoretical disciplines with study in broadly defined "applied" or "functional" fields. It is characterized by the flexibility it provides to each student in the design of his or her course of studies as well as by rigorous research requirements and a heavy emphasis on quantitative methods of analysis.

It offers particular strengths in management science, organizational studies, and finance/economics and continues to attract candidates who look forward to a small-sized program (totaling about 75 students) in which students work closely with each other and a discipline based faculty within the School and the Department of Economics.

This year 26 people were accepted from a pool of 163 applicants; 14 students entered the program (10 men and 4 women), specializing in the following areas: Management Science, 4; Finance, 1; Applied Economics, 1; International Management, 1; Organizational Studies, 3; System Dynamics, 1; Industrial Relations, 2; and Technology of Innovation, 1.

Graduates of the program in recent years seem most likely to accept teaching positions (of the 19 people receiving degrees in 1975, 13 went to university posts, and of the 8 graduates of 1976, 6 are in teaching positions).

A subgroup of the Ph. D. Committee has been meeting at regular intervals during the year to discuss future directions the program might take. Questions regarding program size and breadth, program requirements, demand for graduates, and so on have been raised and discussed. A survey of the faculty is being undertaken at this time in order to ascertain their feelings on these and other issues relating to doctoral study at the Sloan School. At the same time, student opinions are being sought regarding the program's strengths and weaknesses and possible modifications.

Perhaps the greatest problem facing the program is related to funding. Competition among the top business schools for the best applicants is exceptionally vigorous. The fact that the Sloan School has essentially no fund income nor operating budget items for doctoral support means that we are unable to meet the financial needs of many of our admitted applicants and thus frequently lose good people to other schools. (This year, for example, our "yield" has dropped significantly; of the 24 offers of admission extended by the School for 1977-78, only 9 have been accepted to date. This is almost certainly due to our inability to match our competition's financial aid offers.)

The demise of Ford Foundation grants, National Defense Graduate Fellowship Programs, National Science Foundation Fellowship Programs, and the reduction in other sources of external support have hurt badly. Furthermore, while most of our continuing students are earning at least some part of their support through research assistantships or teaching assistantships, the rest must come from savings or loans. It seems to a number of our second- and third-year students that their primary goal has shifted from making progress in the program to one of finding dollars to pay for tuition, fees, and living expenses. For effective education these priorities must clearly be reversed.

In addition, but at a less critical level, the lack of office space (or even suitable "desk space") constitutes a major aggravation for many students.

Despite these shortcomings, the program's basic quality is being maintained. It is clear, however, that additional funding sources and additional space will soon be necessary to prevent that quality from being eroded.

Alfred P. Sloan Fellows Program

Fifty-four members of the 39th class of Alfred P. Sloan Fellows received the degree of Master of Science in Management on June 6, 1977. It was the largest class in the history of the program.

It is typical of the Sloan Fellows Program to boast a number of firsts each year. The Class of 1977 was no exception. The first Saudi Arabian Sloan Fellow was enrolled in the class. A number of organizations were represented for the first time. These include: Health Management Systems, Inc.; Arabian American Oil Company; Department of Mental Health, The Commonwealth of Massachusetts; Office of Housing, Department of Community and Economic Development, Rockville, Maryland; US Department of Housing and Urban Development; Regis College; Mitsui & Company, Ltd.; School of Medicine, New York University; The World Bank; Earth Resources Company; and Levi Strauss Germany GmbH.

Members of the class came from the public and private sector, from the United States and abroad: 36 from US and foreign industry, 7 from US and foreign governments, and 11 from other parts of the public sector of the US (including 6 from the field of health management).

The variety of backgrounds reflects dramatically the multifaceted world of today within which managers play a key role. The demand for the program -- from both the public and the private sector -- continues strong. Most organizations that have nominated executives over the years continue to do so, and interest on the part of new organizations is generated each year. The quality of the nominees is high, as reflected by academic accomplishments and outstanding work experience. A small backlog of nominations continues to grow and all aspects of the program are under constant and close review.

Professor Charles A. Myers, who holds the Alfred P. Sloan Fellows Chair, continues to serve as a member of the Sloan Fellows Program Committee and as Co-chairman of the Selection and Evaluation Sub-Committee and has contributed for many years to the academic and administrative success of the program.

Health Management Executive Development Program

The Health Management Executive Development Program completed its second year as an integral part of the Alfred P. Sloan Fellows Program. The program, aimed at mid-career health care practitioners, educators, researchers, and administrators, continues to attract professionals who wish to prepare themselves for career growth and increased managerial responsibilities in the health field.

Once again, six professional men and women were admitted to the new program: two medical school deans, one psychiatrist, one medical doctor serving as a Scientific Attache at the French Embassy (Washington, DC), a physiotherapist working in the area of mental health, and a researcher in the health area. The interest in the program on the part of medical people continues to grow although the number of participants may tend to fluctuate during the next few years as the enrollment approaches a steady-state objective of 10 to 12 nominations per year.

The program continues to be managed by Professor Edward B. Roberts in collaboration with Associate Dean Peter P. Gil, who manages the Sloan Fellows Program.

M. I. T. Program for Senior Executives

1977 marked the twenty-first year of the M. I. T. Program for Senior Executives. For the first time an intensive one-week follow-up program for alumni was offered, May 19-25. The follow-up program was designed to update the material the seniors received in the regular program.

There are now more than 1,000 alumni who occupy positions of leadership in many companies and organizations around the world. Demand for the 28 places in the program continues very strong; for the past few years this demand appears to have been unaffected by the economic slowdown. Approximately one-third of the participants in each of the two nine-week programs offered came from abroad. The program's first two women participants were members of the spring session; one works with the IBM Corporation and the other with the Society of Nuclear Medicine.

Professor Arnaldo C. Hax served as chairman of the program's faculty committee; and Alan F. White, an M. I. T. alumnus (Sloan Fellow at M. I. T. in the Class of 1971), continued as the program director.

M. I. T. Program for Urban Executives

The tenth M. I. T. Program for Urban Executives was held at the Sloan School from June 15 to July 13. Part of the teaching load was carried by faculty from the Department of Urban Studies and Planning.

Thirty-two participants from the United States and Canada attended the program. There were a large number of applicants, and not all of them could be accepted into this summer's session. Participants were city and town managers, department heads, and other career public sector managers. Cities represented in earlier programs continue to make nominations on a regular basis.

Professor Daniel M. Holland served as faculty chairman of the program, and Mr. White continued as program director.

Greater Boston Executive Program (G. B. E. P.)

The twentieth session of the Greater Boston Executive Program was held from January 21 to April 29. Increased interaction among the limited number of participants (18 this year) continued to be successful. Class members represented 12 organizations, including three new to the program.

This 15-week, one-day-a-week program continues to receive a very positive reception from the Greater Boston companies who participate in it and has enthusiastic support from its alumni. The 1977 G. B. E. P. alumni reunion in April was well attended by alumni and alumnae with their spouses and all participated in seminars given by Professor Louis L. Banks and Senior Lecturer Gordon F. Bloom, with Professor Lester Thurow as the dinner speaker.

Patricia Macpherson has once again provided effective coordination for this program.

Summer Programs

Eleven Special Summer Session Programs were offered by the Sloan School faculty during summer, 1976. All of these were updated versions of programs that had been successful in previous years and again proved very popular and attracted a wide range of participants.

Professor Peter Lorange, Senior Lecturer John F. Rockart, and Associate Dean Michael S. Scott Morton, assisted by Professor Peter G.W. Keen of Stanford University, offered two consecutive one-week programs -- Management Control Systems and Strategic Planning Systems. These programs drew on a wide range of experience and research findings of the faculty, although the emphasis was primarily on the applicability and implications of various management control systems.

Professor Jay W. Forrester and other members of the System Dynamics Group presented the two-week program: System Dynamics, Methodology and Applications; Emphasis on Industrial, World, Urban and National Issues. The program sessions covered system structure, policy and information flow design, time delays, and so on, and related these factors to emergent system fluctuations and equilibrium states.

Professor Roberts again directed the two summer programs he has offered in the past. In June he was assisted by other members of the Sloan School faculty in presenting the two-week Management of Research, Development, and Technology-Based Innovation. In July he led the one-week program on The Dynamics of Health Service Systems with supporting faculty from Harvard Medical School and other colleges and schools of medicine.

Professors Stewart C. Myers and Richard A. Cohn repeated the two one-week finance programs: Basic Concepts in Financial Management and Strategy followed by Models for Financial Management and Long-Range Planning. Professor Gerald A. Pogue of Baruch College, City University of New York, also participated in both programs.

For the second year Professor Chen offered the one-week program on Computer Systems Performance Evaluation: Modeling, Simulation, and Measurement. He and Professor Liba Svobodova of the Department of Electrical Engineering and Computer Science were the principal lecturers in the program.

Professors Edgar H. Schein and Richard Beckhard repeated their program, New Horizons in the Management of Change and Organizational Development, a one-week "live-in" course conducted at the M. I. T. Endicott House.

Operating Systems, a two-week program presenting material enabling participants to design and analyze current operating systems as well as future ones, was again presented by Professors John J. Donovan and Stuart E. Madnick.

For the third consecutive year, Professor J. D. Nyhart, who holds joint appointments in the Department of Management and Ocean Engineering, directed the one-week program on Ocean Resource Management: Legal and Policy Aspects. He was assisted by Professors C. Chryssostomidis and John Devanney of the Department of Ocean Engineering. Professors R. R. Baxter and Louis B. Sohn of Harvard Law School, and Susan B. Peterson of the Woods Hole Oceanographic Institution.

These summer programs, designed to give specific post-experience training to managers functioning in a variety of positions were the "proving ground" for some very effective curricular innovations which, when transplanted, serve to improve the quality and the teaching of our longer residential and degree programs in the School.

Industrial Liaison Symposia and Seminars

Members of the Sloan School faculty have continued to lead and participate in symposia and seminars sponsored by the M.I.T. Industrial Liaison Program.

In September Professor Forrester chaired a one-day symposium in Kresge Auditorium on Socioeconomic Change in Industry and in the Nation. Presentations were made by Professor Forrester as well as by Professors Lyneis, Nathaniel J. Mass, and John F. Collins of the System Dynamics Group and Professor Nancy Roberts of Lesley College.

In October, also in Kresge, a two-day symposium on Business Challenges: An M.I.T. Perspective was held under the chairmanship of General James B. Lampert, Vice President for Resource Development. Sloan School faculty participating in the program included Professors Roberts, Schein, and Forrester, and Dean William F. Pounds.

Late in October, Professor Lorange went to Los Angeles to conduct an afternoon seminar on Strategic Planning Systems -- Recent Advances.

Members of the Organizational Studies Group of the School also presented a symposium in Los Angeles in January. This program, Management of Human Resources: New Issues and Challenges, was led by Professor Schein. Other speakers were Professors Ralph Katz, Lotte Bailyn, and John E. Van Maanen, and Instructor John E. Paap.

The Center for Information Systems Research group presented a one-day symposium at Kresge Auditorium in May on Evolving Information Systems. Dr. Rockart, Director of the Center, chaired the program, and was assisted by Professors Donovan, Meldman, Chen, Madnick, and Associate Dean Scott Morton.

RESEARCH

The School's teaching program curricula and design derive in large part from the extensive and diverse research interests and activities of the faculty, staff, and students.

This section summarizes the major research efforts and accomplishments of the School. The work is both disciplinary and multidisciplinary in character and the groupings below are necessarily arbitrary and may not always reflect the cross-disciplinary and cross-functional mix entailed in both the design and execution of the research described.

Human Factors in Management

The faculty in the organization studies area and in the manpower and labor relations area take as their primary research focus the human issues involved in the management of an organization or in the relation of organizations to one another and to the economic, social, political, and environmental contexts within which they function. The social and behavioral sciences of psychology, sociology, economics, and so on are the disciplinary bases upon which much of the research here builds.

Organization Studies. Several members of the faculty are continuing to focus on the problems of adult socialization, career development, and the interaction of work, self, and family issues throughout the life cycle of men and women in different occupations. While work so far has tended to focus on people in technically based careers, managers, and some urban

workers, plans are developing for a broader, comparative longitudinal approach to a wide range of occupations. The goals are 1) to better understand how such interactions at different life stages lead to patterns of productivity, creativity, job satisfaction, and accommodation among different life concerns; 2) to improve the activities of human resources planning and career development within organizations; and 3) to help individuals to plan more productive and satisfying lives. Specifically:

Professor Van Maanen is continuing his research on the characteristics of different kinds of work settings in different occupations and how these settings produce certain patterns of socialization of new recruits into the occupation, leading ultimately to a general theory of occupational socialization. Professor Van Maanen has carried out further participant observer studies on workers in a variety of organizations and has continued to work with Professors Bailyn and Schein on the changing relation of work and careers, family and self-development. He edited and contributed to Organizational Careers, a volume which summarizes much of the work of the Organization Studies Group in the area of career development and which was published in 1977 by John Wiley & Sons.

Professor Bailyn is continuing her study of accommodation patterns in educated adults, especially in dual career families. The differential impact of family and work issues on men and women at different life stages is of particular importance in this research. Professor Bailyn contributed a chapter on such life-career considerations as an indicator of quality of employment to a volume on measuring work quality for social reporting purposes. The chapter was coauthored with Professor Schein. Professor Bailyn also has finished a paper on patterns and determinants of work involvement in technically based careers which appears in the joint volume summarizing the group's career development research.

Professor Katz is continuing his analysis of the determinants of job satisfaction, especially as a function of career variables such as job longevity. This seminal research shows that people who have been in the same job for long periods of time are much less responsive to job enrichment, getting more of their satisfaction from contextual and organizational rewards. Professor Katz is extending this work to an examination of productivity and commitment both in individuals and groups as a function of job longevity.

Professor Schein is continuing his analysis of the 1961 panel study showing that career anchors develop or become manifest early in the career and subsequently serve as constraints on future career decisions. Currently he is working on more general models of how organizations plan for and develop their human resources throughout the life of the individual career occupant. This work is an effort to improve human resource management at all stages of the career.

Associate Dean Gil and Professor Schein are continuing studies of career paths of Sloan School alumni and are developing methods of analysis which permit the identification of such patterns from career history data. Judy Gordon, a doctoral candidate, is completing her thesis on the effects of congruence between personal orientation toward a job and actual job content on job satisfaction and organizational commitment.

Professor Beckhard is continuing his survey of mid-career crises in high potential managers. Working primarily with cases uncovered in relation to his extensive consulting activities, Professor Beckhard is generating hypotheses concerning the reasons why an increasing number of high potential managers are turning down promotions and leaving organizations in which they have high career potential. Professors Beckhard and Schein are exploring the value implications of these data in relation to societal changes in values.

The work on career development is increasingly connecting with the second major research area in the Organization Studies Group conducted by Professor Allen. Professor Allen and

his colleagues, Professors Roberts and von Hippel and Mr. Paap, continue to unravel the factors which aid or hinder the process of innovation and technology transfer. A decade of research on R&D management has contributed many valuable insights which will be summarized in Professor Allen's forthcoming book, Managing the Flow of Technology: Technology Transfer and the Dissemination of Technological Information within the R&D Organization.

Another major area of research within the group is related to improvement of health care delivery through the design and study of educational interventions, particularly at the management level. This research is discussed below in the section dealing with health care management.

Though the research efforts of individual faculty members continue to be largely guided by the requirements of their own project and the scientific issues they are trying to address, there is a growing communality of both scientific and practical concerns evident in the group. In particular, we see a growing concern for the development of theory in the art of applying knowledge and translating scientific findings into the practical arena of management. Many of the members of the faculty are actively engaged in planned change and organization development activities, and this applied or clinical focus of the groups continues to be one of the main sources of strength.

These efforts are especially enhanced by the research projects undertaken by Professors Beckhard and Reuben T. Harris on the effects of different kinds of planned change interventions, especially in large and complex systems. Research in this area has been sparse, but a major effort to locate change projects and to measure the effects of different approaches to change is being launched not only in health care delivery, but in industrial organizations using organization development activities, and urban systems attempting to improve urban management. Professor Harris has designed a survey to evaluate the effects of a major ongoing organization development program on employee attitudes, costs and profits in a number of the organization's work units.

Professor Harris has, in addition, studied the relation of a health care organization's orientation toward patients and the formal structure of the organization. He also has sought to discern the organizational conditions affecting the use of "physician extenders," like nurse practitioners or physician assistants, in the delivery of health care in the military services.

Professor Leo B. Moore continues to work on the factors which lead to creativity and innovation in the management process and to review a variety of experimental approaches with "management by objective" programs in a number of companies.

Manpower and Labor Relations. Research in this area has proceeded along a number of lines -- group and individual, funded and unfunded.

Professors Bailyn (from OSG), Phyllis A. Wallace, and James W. Driscoll have been working since summer, 1976 on an exploratory research project focused on a centralized training center of a large New England company. A report on this preliminary research was submitted to the company in April, with a proposal for funded support for future work. The principal purpose of the research is to investigate how management training and development centers might be used to increase organizational effectiveness and job satisfaction.

In addition to leading this research effort, Professor Wallace has completed a manuscript built on the papers and proceedings prepared for earlier M. I. T. -Industrial Relations Section workshops on equal employment opportunity and originally funded by the National Science Foundation. The book was published under the title Women, Minorities, and Employment Discrimination, by D. C. Heath/Lexington Books in April 1977. Annette La Mond (Sloan

School, Class of 1974) was coeditor. Another of her ongoing research projects is a study of upward mobility of women in management which will, among other things, seek to track the careers of women Sloan School graduates since 1975. Women graduates will be matched with their male peers, and data will be collected from both groups over a five-year period. Further funding is being sought to permit in-depth interviews following the questionnaire analyses. Professor Wallace is also completing a monograph, "The Employment Status of Black Women;" and she is beginning a separate study of "The Dynamics of the World of Work" in which employment policies (internal and external to the firm) will be linked to issues related to equal employment opportunities.

Among other publications by Professor Wallace during the year was her contribution, "A Decade of Policy Developments in Equal Employment and Housing," in R. Haveman (editor), A Decade of Federal Anti-poverty Programs: Achievements, Failures, and Lessons, Academic Press, New York, 1977, and her M.I.T. Press book, Equal Employment and the AT&T Case, was included in the annual list of "Outstanding Books in Industrial Relations" published by the Industrial Relations Section at Princeton University in May.

Professor Charles Myers co-directed with Professor Thomas A. Barocci the third and final year of the research contract with the Office of Research and Development, Employment and Training Administration, US Department of Labor. This project has investigated the impact of the Comprehensive Training and Development Act of 1973, as compared with pre-CETA programs, in Cambridge, Lowell, New Bedford, and the "balance of state" (with emphasis on the Quincy and Newton areas). Three more Sloan School Master's students majoring in industrial relations worked on this project and wrote theses, as did other students in each of the prior two years. Professors Barocci and Myers will complete the final report on this three-year research project during the summer.

The eighth edition of Personnel Administration, by Professor Emeritus Paul Pigors and Professor Myers, was published by McGraw-Hill last fall; Professor Myers also drew on his experience for an article, "Arbitration of Disputes over New Contracts," Sloan Management Review, fall 1977; and presented a paper, "National Manpower Strategies," at the 50th Anniversary Conference of Industrial Relations Counselors, held at the University of Virginia. This was subsequently published in the conference proceedings.

Professor Barocci has been engaged in a number of research projects, in addition to the one mentioned above with Professor Myers. Jointly with Visiting Associate Professor David B. Lipsky (visiting from Cornell University), Professor Barocci evaluated the economic impact of the final offer arbitration law in Massachusetts on the salaries of police and firefighters in cities and towns in the state. A preliminary report on this research, "The Impact of Final Offer Arbitration in Massachusetts," was released publicly on May 17, as the Legislature was debating the issue of continuing the law for another two years. Some funds were provided through the Sloan School for this policy oriented research. A final monograph will be completed during the summer.

At the request of the National Council on Employment Policy, Professor Barocci prepared a paper on the use of public work as a countercyclical and economic development tool, for presentation at a conference on Job Creation at Michigan State University in May. This paper will be published in the conference proceedings, and a longer monograph is under consideration for publication by the National Council on Employment Policy, Washington DC. Professor Barocci is also continuing work with the Harvard-M.I.T. Joint Center for Urban Studies to obtain a grant to study the economic development of New England. Among his recent publications are: "Planning and Economic Development under CETA," Adherent, August 1976; and a Sloan School Working Paper, "Public Works Projects in the US: Economic Development and Countercyclical Programs from FDR to the Present."

In addition to the research with Professors Wallace and Bailyn, Professor Driscoll began in May a year-long study supported by a grant from the Office of Policy Evaluation and Research, US Department of Labor. He will examine the strains created for individual negotiators by their processes of negotiation and for the existing union and management organizations by their attempts at cooperative problem solving. Three types of cooperation are being studied: the Joint Labor-Management Committee in the Retail Food Industry; a quality of work life committee at a large urban hospital; and a series of joint meetings in a manufacturing plant. Also included are exploratory studies of the Scanlon Plan, begun with the cooperation of Fred Lesieur, a consultant on the plan and frequent lecturer here. Professor Driscoll hopes to develop some guidelines from a behavioral science perspective for building more effective joint problem solving into what have been traditionally adversary relationships.

Professor Driscoll's publications include "Trust and Participation in Organizational Decision Making as Predictors of Satisfaction," accepted by the Academy of Management Journal; and "Why Individual Academics Want a Union: Two Case Studies," a Sloan School Working Paper now under consideration by a refereed journal. Another Sloan School Working Paper, "A Structure for Problem Solving between Union and Management," appeared in May and was the preliminary statement of the research now under way, mentioned above.

Professor Kenneth S. Mericle is working on some papers from his longer manuscript on possible employment transfer effects in the US of the inducements offered by the Brazilian government to US automobile manufacturing firms to establish complete plants in Brazil. One aspect of the study is the effect of this effort on the Brazilian balance of payments. This research was part of the International Business Project of the Sloan School and was funded by a grant from the US Department of Labor. Professor Mericle's field study drew on his earlier research in Brazil on the system of industrial relations there under the military government. A long article, based on the latter study under the title "Corporist Control of the Working Class: Authoritarian Brazil Since 1964," was published in a volume edited by James Malloy, Authoritarianism and Corporitism in Latin America, University of Pittsburgh Press, 1977. Professor Mericle is also completing a study of the patterns of labor relations and collective bargaining in the urban mass transit industry and the implications of these patterns for the adoption of new service innovations for mass transit. This is part of an interdisciplinary research project on "New Perspectives on Urban Transportation: Strategies for Overcoming Barriers to Innovation," under the direction of Professor Alan Altshuler of the Department of Political Science, and funded by the US Department of Transportation.

Mr. Jacks has continued his studies of the implications of recent Supreme Court decisions affecting labor, some of which have concentrated on affirmative action issues rather than the traditional areas of labor-management relations.

Professor Lipsky is preparing, before he returns to Cornell University in July, an edited manuscript of papers and discussions resulting from the Conference on Labor-Management Relations, Employment, and Related Issues, held in March to commemorate the Fortieth Anniversary of the Industrial Relations Section and the Twenty-Fifth Anniversary of the Sloan School. Five ex-Secretaries of Labor spoke, and former Secretary George P. Shultz sent a paper to be read; a panel of top management and labor representatives discussed the ex-Secretaries' comments and other issues as well. The conference manuscript will be published as a book or monograph sometime in the fall.

Economics and Finance

The Economics and Finance Group is the second basic disciplinary pillar upon which the School's research and teaching programs build.

Professor Sidney S. Alexander, head of this group, was principally engaged in research on the foundation of normative judgment in the social studies. In particular, he worked on an attempt to balance off a "rights" or procedural approach with the standard utilitarian approach.

Professor Thurow's research continued to focus on the factors that generate and alter the distribution of income and wealth. His publications during the year included: "Optimum Trade Restrictions," Econometrica, fall 1976; "Agriculture: The American Dilemma," New Society, fall 1976; "The Implications of Zero Economic Growth," Challenge, March/April 1977; and "Government Expenditures: Cash or In-kind Aid?" Philosophy and Public Affairs, summer 1976. In addition he returned to an earlier interest and completed a study for the Joint Economic Committee on the economic techniques for allocating research and development funds.

Professor Franco Modigliani's research during the past year has been devoted to three interrelated areas. The first area is that of stabilization policies and the problem of stagflation. These issues were the focus of his presidential address presented at the annual meeting of the American Economic Association. Further research and papers in this area have dealt with the cost of unemployment and inflation and implications for the management of aggregate demand, and with problems of the application of optimum control techniques to stabilization policies. In this context, Professor Modigliani has also been concerned with the special problems faced by stabilization policy in a country like Italy where wages are, for the most part, fully or more than fully indexed.

A second continuing interest focused on the life cycle hypothesis of saving. Professor Modigliani is applying this model to the further study of intercountry differences in saving behavior, and in particular, to the effect of social security arrangements. He is also applying it to the study of the role of property income and the return to capital in national saving. Finally, Professor Modigliani has continued his work on the term structure of interest rates and the implications of efficient markets.

Third, Professor Modigliani has been concerned with organizing the second and third conferences in a series designed to bring together central bankers and academic economists. The second conference was held in Athens, Greece in October 1976 and was devoted to "The Political Economy of Inflation and Unemployment in Open Economies." The third conference will be held in September 1977 in Vienna and will be devoted to "The Economic Crisis of the 1970s: Lessons for Stabilization Policy."

Professors Holland and Stewart Myers continued their study of trends in corporate profitability and capital costs for a study group of the Committee for Economic Development. Their research evaluates the recent "decline" in corporate after-tax profitability and market valuation in the longer-run context -- over the full sweep of years 1929-1975. It is closely related to the International Business Project's exploratory study of international comparisons of the rate of return to capital, on which Professor Holland has been engaged. A second meeting of the group participating in this latter exploratory project was held in April 1977. At this meeting reports incorporating major new research findings were presented for a number of countries. A promising groundwork has been laid for the development of rate of return estimates comparable over time within each country, and comparable as well across countries. These estimates would enrich our understanding both of the respective national economies and their interaction.

The results to date for the US (the Holland-Myers study), the United Kingdom, Italy, Japan, and Germany are encouraging. The School hopes to find funding to extend the study to include a number of other countries.

Continuing his research in property taxation, Professor Holland is also preparing a report on the Caribbean experience with site value taxation. He also prepared papers for the American Assembly in October 1976 on the role of tax policy in capital formation and for the Institute of Fiscal Analysis on the effects of taxation on executive incentive. He continued as editor of the National Tax Journal.

Professor Edwin Kuh continued on half-time leave to serve as Executive Director of the National Bureau of Economic Research Computer Research Center for Economics and Management Science, an organization which conducts algorithmic and software development research on data analysis methods, econometric estimation, and mathematical programming.

Together with Professor Roy E. Welsch, Professor Kuh published an article on "The Variances of Regression Coefficient Estimates Using Aggregate Data," Econometrica, March 1976. He also delivered the keynote address to the national conference of the Association of Computing Machinery and participated in a joint meeting of US and Russian economists on issues in economic modeling held in Moscow last summer.

Professor Robert S. Pindyck worked with Professors Henry D. Jacoby and Morris A. Adelman (of the Department of Economics) on an interdepartmental project to study the world oil market. Professor Pindyck developed econometric models to describe and predict international demands for alternative energy resources, performed studies of potential OPEC cartel behavior, and studied the potential for international cartelization of other exhaustible industries. Professor Pindyck also worked on a number of theoretical and empirical issues in natural resource exploration, production, and pricing. He also continued his research into the application of control theory to economic policy. Professors Pindyck and Kuh continued work under their National Science Foundation (NSF) grant on these and related studies of optimal control applications in economics. Finally, Professor Pindyck worked with members of the Policy Study Group of the Energy Laboratory on a study of energy policy options for the United States.

Professor Robert C. Merton continued his research on the pricing of options and of corporate liabilities and more generally, on the operation of financial markets. His work continues to be supported by NSF and he has continued to publish a number of significant papers on these topics. Several of the papers dealt with the impact on option pricing of discontinuous underlying stock returns. Others dealt with growth under uncertainty and with a reexamination of the capital asset pricing model. Professor Merton also continued as coeditor of the Journal of Financial Economics and associate editor of the Journal of Finance and the International Economic Review.

In addition to his work with Professor Holland, Professor Myers's research was devoted mainly to issues in corporate finance. He continued research on applications of option pricing theory to the firm's borrowing decision, and of the capital asset pricing model to the firm's investment decision. He also participated in an Energy Laboratory study of US government support for "commercialization" of new energy technologies.

During the year, Professor Donald R. Lessard has been engaged in research on financing and ownership alternatives for large-scale extractive projects in developing countries. He completed a paper with Professor Edward M. Graham in this area, "Discount Rates for Foreign Mining Ventures," and prepared a paper for the Ministry of Mines of the Government of Bolivia through the Harvard Institute for International Development entitled, "Opportunities for Improving Mining Finance in Bolivia."

He also continued his work on alternative mortgage instruments with the Joint Center for Urban Studies, presently concentrating on a study of borrower reactions to various alternatives.

He prepared papers for two conferences: "Transfer Prices, Taxes, and Financial Markets: Implications of Internal Financial Transfers Within the Multinational Firm," for the New York University conference on Economic Issues of Multinational Firms, which will be forthcoming in the conference volume; and another for a conference on External Financial Policy sponsored by the OAS-Banco Central de Chile entitled "International Risk Sharing for Commodity Producing Countries: Alternatives to Foreign Direct Investment."

His other publications included: "Large Scale Direct OPEC Investment in Industrialized Countries and the Theory of Foreign Direct Investment: A Contradiction?" with Professor Stephen J. Kobrin, published in the Weltwirtschaftliches Archiv; "Financial Factors and the International Expansion of Small Country Firms," in Multinationals From Small Countries; and "Currency Changes and Management Control: Resolving the Centralization/Decentralization Dilemma," which will be forthcoming in the July issue of The Accounting Review.

Professor Lessard recently received the Graham and Dodd Award from the Financial Analysts Federation for his article, "World, Country, and Industry Relationships in Equity Returns."

Professor Cohn continued his work on implementing new designs for the residential mortgage instrument. He began work investigating the economic foundations of financial accounting and completed a paper with Professor Zvi Bodie of Boston University on inflation-induced bias in measured profitability. Professor Cohn also presented a paper on "Modeling the Implementation of Electronic Funds Transfers" at a conference on Electronic Fund Transfers sponsored by the National Science Foundation.

Professor Fischer Black continued his research on the behavior of economic and financial markets under the assumption that individuals and firms will attempt to take advantage of any profit opportunities they see. His research generally falls into two broad areas: 1) the pricing of options and related securities, and 2) the application of concepts from finance to economic theory.

His publications during the academic year were on corporate investment decisions, the objectives of accounting, the ways in which stock volatilities change, and regulation of securities markets.

Professor Black is currently involved in research on ways of making accurate estimates of covariances among stock returns.

Professor Eli Shapiro continued his research efforts in financial markets and regulation of financial institutions. His Herman B. Wills Lecture at the Federal Home Loan Bank of Indianapolis was published and is in the process of distribution. Together with Professor Kent Colton he delivered a paper on "The Process of Change in the Savings and Loan Industry," which is included in the Conference Proceedings of the Second Annual Conference of the Federal Home Loan Bank of San Francisco. His contributed chapter on "Direct Placements" is being published in a forthcoming volume published by the University of Pennsylvania entitled, Life Insurance Investments. Together with Professor W. L. White of the Harvard Business School, he edited a volume, Capital for Productivity and Jobs, which was published by the American Assembly.

Professor Frederick L. A. Grauer was on leave at the University of British Columbia during 1976. In 1976, an article on equilibrium in an international capital market (coauthored with Professor R. H. Litzenberger of Stanford University and R. E. Stehle of the University of Mannheim) appeared in the Journal of Financial Economics and a discussion appeared in the Journal of Finance. On his return to M.I.T. in 1977, Professor Grauer continued his studies of the pricing of commodity futures contracts, inter-temporal equilibrium in commodity markets, and monetary rules under uncertainty, and revised several coauthored papers

in these areas. A paper on the empirical behavior of percentage price changes of commodity futures contracts was also completed. His current research involves analysis of the relationship between foreign exchange risk and the financial policy of a multinational firm and models of price change for commodity futures contracts.

Management Science

The Management Science Group is the third of the Sloan School's principal foci of teaching and research. The group is broadly concerned with models, measurements, and information systems and their impact on managerial processes in a variety of settings including planning and control, marketing, and operations management. The research of the group can be roughly divided into context related research that deals with specific areas of management concern and into methodological research on general tools and techniques. Using this dichotomy, the application areas can be further subdivided into public and private sectors.

A major concern in the public area has been energy. The work has been heavily interconnected with other parts of the Sloan School and of M. I. T., particularly with the Energy Laboratory where Professor Jacoby is a member of the Steering Committee. Professor Jacoby is one of the architects of an Energy Policy Study Group and he, Professor Donovan, and a group of students have designed and implemented a New England Energy Information System and a generalized software capability called GMIS for data manipulation and analysis. Professor Gordon M. Kaufman has conducted an extensive project to model the process of oil and gas exploration. His methods permit better estimates of undiscovered oil and gas reserves. He is currently working in cooperation with the Interagency Oil and Gas Project, which is developing an official Department of Interior position on US oil and gas resources. Professor Jeremy F. Shapiro has been investigating development of mathematical programming models of energy systems so as better to be able to evaluate US policy alternatives with medium-term planning horizons. Dr. Bloom in his continuing work with the food industry is currently focused on energy conservation in supermarkets where refrigeration accounts for substantial national consumption.

Also in the energy area Professors Barnett, Gary L. Lilien, and John D. C. Little have started a project on the industrial adoption of photovoltaic devices. The work is being done in cooperation with the Energy Laboratory and Lincoln Laboratory. The goal of the work is to develop models and field measurements to help determine in what sectors, geographical areas, and points in time the government should install photovoltaic field-test projects so as to best encourage the development and diffusion of the technology. In addition, methods are being devised to provide user feedback for the R&D process so that design improvements can be accelerated.

In other public sector activities, Dr. Rockart has studied the planning and control aspects of health systems and, in particular, has been concerned with a methodology for planning management information systems in public organizations. Professor Thomas L. Magnanti has studied large-scale transportation network problems through the decomposition techniques of mathematical programming. Professor Barnett's statistical work on victimization from crime has attracted wide attention among people concerned with urban problems because it reveals a remarkably high probability that people living in certain areas will have crimes committed against them. In further work he is examining the statistical evidence for the deterrent effect of capital punishment.

In the private sector a variety of work has been going on, especially in the areas of marketing and operations management. In marketing, Professors Alvin J. Silk and Glen L. Urban have devised measurement techniques and supporting models to predict long-run market shares for new products prior to the expensive and often unreliable step of test marketing. In

addition, Professor Urban has developed related techniques for a new product design and positioning, and Professor Silk has been studying the qualities of advertising and their relationship to customer response. Professor Manohar Kalwani is studying a hierarchical approach to product segmentation as a means of understanding competitive relationships in a market. Professors Lilien and Little are in the second phase of a major study of industrial marketing, the ADVISOR Project, in which a group of cooperating companies have provided cross-sectional marketing data on a large sample of products. The study seeks to determine how industrial marketing budgets are related to product and market characteristics. Professor Little has further been investigating the marketing measurement capabilities of point-of-sale data collected automatically through the Universal Product Code system.

Although management science techniques have long been helpful to companies in designing and installing production planning systems, a number of difficulties plague applications. Particularly serious has been the compartmentalization of problems into small systems that really should be connected into large ones. At the same time, large complicated systems have often collapsed as the designers have moved on to other responsibilities. Professor Hax is engaged in a project on hierarchical production and distribution systems which seeks to tackle these issues. In his work, models for higher level strategic decisions set constraints for more local tactical decisions from which the latter feed back information to the former. Closely related is the work of Senior Lecturer Harlan C. Meal, who is concerned with relating aggregate inventory control to individual stem decisions. In addition, Professor Magnanti, along with Professor Hax, is studying new methods of production and inventory scheduling using large-scale optimization theory. Professor Hax has further embarked on new research on strategic planning in diversified organizations.

The ability to extend knowledge and solve problems in context areas such as those cited above depends on continued basic methodological research. Considerable activity along these lines is taking place within the Management Science Group. Professor Lorange is studying formal planning systems, especially in the complex setting of multinational corporations. He is studying a group of large corporations to determine their effectiveness in adapting to environmental change. Professor Lorange is also conducting research on the elements of successful administrative systems in small corporations. In related work, Lecturer J. Morrison McInnes has studied the design and use of financial planning models in the planning and control functions. This has involved field research in 15 companies. Professor Michael F. van Breda has conducted a study of corporate earnings and finds that certain high profit rates attributed by some researchers to barriers of entry may be purely accounting induced phenomena.

A major methodological thrust within the group is mathematical optimization. Many large-scale systems are potentially capable of improvement by these techniques. A surge of theoretical developments in recent years has not yet been well integrated into practice because of lack of adequate computational support and because of a few important stumbling blocks in the theory. Recent research by Management Science Group faculty has been directed at these issues. Professor Jeremy Shapiro has been supervising the development of a modular system of mathematical programming packages at the National Bureau of Economic Research installation in Cambridge. He has also focused research effort on certain outstanding issues in integer and mixed integer programming. Professor Magnanti has been attacking problems in combinatorial theory and nonlinear programming and has had a particular concern for optimization in large linear programming models and sensitivity in nonlinear optimization models. Professor Marsten has brought together two previously separate mathematical programming methods, branch-and-bound and dynamic programming, and discovered that substantive new computational efficiencies can thereby be gained.

At emerging concern among statisticians is the distortion of estimation and inference by "bad" data. This has given rise to the field of robust statistics. Professor Roy E. Welsch has

been developing robust nonlinear regression techniques and implementing them on easy-to-use computer systems. In addition he has focused on the most widely used multivariate technique, multiple linear regression, and has been developing new kinds of diagnostics for understanding the statistical properties of the results.

Computer based information systems consume large quantities of resources in the national economy and generate more than their share of concern and controversy. Stimulated in part by the stringent requirements of energy information systems that can be used for policy analysis, Professors Donovan and Madnick have been laying foundations for a computer system architecture that allows multi-user access to a single data base and affords access to multiple and potentially incompatible data base management systems. In related work, Professor Chen has worked on a theory of data base design and on analytic models for use by a data processing manager to select the most cost-effective computer system configuration. Professor Meldman has been concerned about the interface between computers and law, both from the point of view of legal issues, such as privacy, and applications of computers within the legal system. He has also been investigating petri-nets as an information system planning tool.

The importance of computers and computerized decision support systems is further reflected in the activities of the Center for Information Systems Research (C.I.S.R.). Dr. Rockart has assumed the post of Director of the Center, following Professor Scott Morton's appointment as an Associate Dean of the Sloan School. C.I.S.R. draws on industry funds for use in critical management issues involving computers and performs a key communication function between researchers at the School and potential industrial users of the research. As part of this effort, the Center organized a four-day seminar on current issues in information systems research during summer, 1976. Dr. Rockart himself is engaged in a study of distributed computing power in large organizations. This has become an area of great interest as dropping hardware costs have brought on a new generation of minicomputers and microprocessors with a great potential for improving management processes.

System Dynamics

System dynamics research has continued to concentrate on the Group's socioeconomic model. Development of the National Model has entered a new phase of assembly in which previously tested sectors are being brought together. Production sectors, labor mobility networks, the banking system, and consumer sectors have been separately evaluated and are now being interconnected. The project is directed by Professors Forrester and Mass with the assistance of Professors Dale Runge and William A. Shaffer.

New insights from the Model involving cyclical behavior in the economy, especially the 50-year long wave that seems to have produced widely spaced major depressions, has led to three invitations for testimony before Congressional committees.

Financial support for the System Dynamics National Project is now diversified and about 20 individuals and corporations are currently participating in the program.

A group in system dynamics has also been developing a curriculum on the behavior of social systems to be taught in the primary and secondary schools beginning at about the fifth-grade level. Development of the teaching materials has been under way for several years with demonstration teaching in local schools. Participants include M.I.T. graduate students and faculty members of several other schools. The group is led by Dr. Nancy Roberts.

Application of system dynamics to corporate policy is being expanded under the leadership of Professor Lyneis. System dynamics originally started as an application to understanding

corporate behavior and developing improved management policies. In the last few years attention has shifted to larger social systems. Now additional faculty strength permits parallel pursuit of industrial as well as national economic applications.

Professors Runge and Forrester also have been working with faculty members of the School of Engineering to develop a system dynamics subject for undergraduates. The subject is being jointly sponsored by five departments and will be open to all undergraduates including first-year students. The purpose of the subject is to show the common foundations underlying the several fields of engineering as well as the common foundations connecting engineering to medicine, economics, social systems, and management. The subject will be jointly taught by faculty of the System Dynamics Group and the School of Engineering.

Management of Technological Innovation

The Sloan School continued to maintain its active program of teaching and research on the problems of generating effective technological innovation. Efforts were concentrated on aspects of R&D staffing, structure and strategy, and their integration in the corporation and/or government agency.

In regard to staffing of research and development organizations, Professor Katz has joined with Professor Allen in a new major study of the management of technical groups. Funding from the Department of Defense will permit examination of a large sample of engineers and scientists to attempt to relate variables such as group age and composition, leadership, technical communications, and environmental interactions to the performance of technical groups and projects.

Professor Roberts has extended his interests in critical performers in the innovation process. In a related study by Dr. Richard Rhoades, the extent to which laboratory performance depends upon a balance among creative scientists, entrepreneurs, gatekeepers, program managers, and sponsors was measured and analyzed. The research revealed special sensitivity of perceived laboratory R&D effectiveness to the entrepreneurial and market gatekeeping functions. Further data analysis will be undertaken with the information gathered from five government laboratories.

In the area of structure, Professor von Hippel has continued to focus on the relationships between users and manufacturers of innovative industrial goods. Professor von Hippel has shown previously that the locus of innovation most frequently resides in the user organization, rather than among the suppliers of scientific/analytic instruments and semi-conductor and electronic subassembly production equipment. Professor von Hippel has been developing a theoretical framework for extending the implications of this research to industrial organization and governmental policy considerations. Professor von Hippel has also been studying with Dr. Stan Finkelstein the linkages between users and innovators in the area of clinical laboratory technology.

Professor Allen's decade of research on technical communications has been integrated into a book published during the spring by the M. I. T. Press. His research has been concerned with the acquisition of new technology by organizations and the effective dissemination of this information within organizations for technical problem solving. Recently, Professor Allen has turned his attention to these issues of technology transfer at the national level. His continuing research in the Republic of Ireland has now been paralleled by the M. I. T. Center for Policy Alternatives in a study in Brazil, and Professor Allen is now initiating a new collaborative effort with the Center for Policy Alternatives on the role of research institutes in technology transfer and economic development.

Some of the more interesting results from Professor Allen's national studies involve marked differences in the ways that scientific disciplines structure themselves for international communication. A field experiment has just been completed in which the communications patterns in one discipline were examined under conditions of radically changing economic relevance.

In regard to strategy, Professor Roberts continued his interests in corporate new venture organizations and in the formation of new enterprises. With Dr. Finkelstein, and support from the Health Sciences Fund, Professor Roberts will be looking at the formation and development of medically oriented technical ventures. He is also reviewing the role of technical planning as part of overall corporate strategic planning and is assessing the several new methods that are aimed at integrating technical inputs into financial and marketing based plans.

During the past year the Center for Policy Alternatives expanded upon Professor Roberts' earlier research on new company formation to examine conditions for technology based economic growth in multiple regions of the world. The Center staff gathered data in the US, Canada, and Europe, prepared two major research reports for their French government sponsor, and helped develop a major policy conference in France on the implications of the research. Professors Roberts and Allen presented papers at that meeting, along with several other M. I. T. staff members.

The joint M. I. T. -Harvard Business School Program on the Management of Technology organized a semester-long seminar on corporate technological strategy. Professors Roberts and Richard Rosenbloom, the David Sarnoff Professors at M. I. T. and Harvard, respectively, conducted this continuing program which brought a dozen leaders of industry to campus for comparative presentations on technical strategy.

During the year the group collaborated with the M. I. T. Alumni Center of New York in developing and presenting a major symposium on the management of technological innovation. Over 450 participants attended the conference, and a series of coordinated publications in Technology Review are now anticipated as an outgrowth of the symposium.

Corporate Strategy, Policy, and Planning

The conglomerate organization was the focus of research of several members of this group. The objective of this work has been to assess the economic performance of conglomerate firms and to explain differences between conglomerate and non-conglomerate organizations across the various dimensions of corporate strategy, internal management practices, organization structure, and planning and control systems.

The individuals involved in this group effort were Professors Hax, Stewart Myers, Edward M. Graham, Henry S. Marcus (Department of Ocean Engineering), Michael E. Porter (Harvard University), and Zenon S. Zannetos. A symposium is being planned for the 1977-78 academic year to bring together about 25 to 30 academicians, people from industry and the government to explore the economics of the conglomerate organization.

Professor Graham is, in addition, conducting research in the areas of technology transfer and its impact on international trade and in the economics of the international extractive industries.

Professor Zannetos has continued his investigation in the areas of oil economics, oil transportation (with particular emphasis on the level and structure of spot and time-charter rates), and the determinants of organization structures and planning and control systems. In addition he has initiated, during the year, two other research activities. One activity centers on the impact of government regulation on objectives of the firm. The purpose of the project is to

examine the degree of transience or permanence of various societal pressures on the firm and to determine the role of government regulation in the process. The second activity attempts to unify the three main theories of the firm -- the economic theory of rational action, the behavioral theory of bounded rationality, and the bureaucratic theory of organizations.

International Management

Professor Richard D. Robinson is engaged in a major study designed to gauge the scope and adequacy of international management education at the graduate level in the United States and Canada. The research, which involves interviews with both leading practitioners and academics, explores the content of international management programs and their adequacy and/or effectiveness. The latter will be judged in terms of both the opinions of academics and practitioners and the career experience of graduates.

Professor Kobrin has completed a quantitative cross-national study which developed and tested a model of the process through which political events affect manufacturing direct investment in non-industrialized countries. He is currently initiating two additional studies concerned with political risk: an investigation of methods used by US multinational corporations to analyze the political environment and integrate political information into decision making and an analysis of the determinants of nationalization of manufacturing enterprises.

Professor Nyhart has completed the initial iteration of his cost model of a deep seabed ocean mining project, which was reviewed in a March workshop sponsored by the Office of Marine Minerals. Further development of the model, and analyses of regulatory options for deep ocean mining is continuing. Professor Nyhart is also completing a study of Federal regulation of offshore structures and uses. He has served during the past year on a National Academy of Engineering Marine Board Panel on Verification of Fixed Offshore Oil and Gas Platforms and on a Society of International Law Panel on International Terrorism.

Two Ph. D. students are continuing work on host government attempts to regulate multinational corporations. Moise Naim is exploring the impact of political and economic factors on attempts to implement the Andean Pact's foreign investment policy in Venezuela. Louis Calvet is analyzing the Canadian foreign direct investment review process. Two other projects involve widely disparate aspects of the international utilization of technology. Vinod Dar is investigating the economies of supra-national resources. Shing Fung is continuing his study of government control of international technology transfer in Brazil.

Health Care Management

During 1976-77 the Sloan School continued to build its one-year old program in health care management, introduced new academic subjects in the area, increased the scope of related research and institutional relationships, and continued efforts to expand faculty and resources in this relatively new area.

The Sloan School extended its active collaboration with the Association of American Medical Colleges (AAMC) in an ongoing multi-phase program involving the development and presentation of management education programs for the AAMC's constituent medical schools. Professors Beckhard and Roberts, representing the applied behavioral sciences and the management sciences, respectively, exercised joint responsibility for design and leadership of these activities, with active involvement of Professor Schein, Dr. Rockart, and numerous faculty recruited from other universities. Phase I has involved nearly every dean of the 130 North American medical schools in a one-week management program. More than 70 medical

schools have already participated in the follow-up Phase II program which emphasizes problem solving of real issues identified by the medical schools, with more than a dozen medical schools returning for a second time to accelerate programs of managerial improvement initiated by the earlier phases. Additional sessions of this M.I.T. /AAMC program are scheduled for coming years, with the program's sponsor, the Robert Wood Johnson Foundation, recently announcing a three-year continuation of funding. During the past year, additional Phase I-type programs were developed and presented to directors of teaching hospitals and to chairmen of academic departments of medicine, and these are also continuing. In a related activity with the AAMC, Dr. Rockart continued a short course for the business and planning officers of the medical schools, attended by over 150 persons thus far. Sloan School faculty have also been involved in presenting similar management education efforts to deans of pharmacy schools and chairmen of surgery, radiology, and pathology departments.

Professor Harris broadened his research on the client orientation of health care organizations, in cooperation with Visiting Professor Norman S. Stearns, Associate Dean of the Tufts Medical School, and Dr. Robert Amick of the Boston Veterans Administration Hospital. These three collaborators are developing a post-hospitalization assessment of patient care. Dr. Stearns will focus on patient compliance with doctors' orders and Dr. Amick will concentrate on measuring after the fact the appropriateness of medical care.

Dr. Rockart advanced into the data analysis stage of his studies of "disease costing" in in-patient and out-patient settings. Doctoral research by Colin Lay, under Dr. Rockart's supervision, indicates wide variations in care costs for supposedly similar disease diagnoses. Dr. Rockart's latest research interest is on the possible role of distributed information processing systems to aid patient management in hospitals. He and Christine Bullen have prepared a major proposal for testing a methodology for information system structuring. They plan to expand this methodology in the coming year in several collaborating hospitals in the Boston area.

In another area, Professor Alvin Drake of the M.I.T. Operations Research Center, along with Dr. Finkelstein, a new addition to our health management group, and Professor Harvey Sapolsky of the Department of Political Science are coauthoring a book-length manuscript on blood banking management and policy. New efforts continued in the transfer of research approaches developed earlier in the area of management of technology to problems of health care technology. Professors Roberts and von Hippel began a collaboration with Dr. Finkelstein to examine factors affecting the development and commercialization of health innovations. Initial study is under way of user-innovator interfaces in regard to clinical laboratory instrumentation, and a research design has been completed for examining entrepreneurial activities in the health care area. Professor Roberts and Dr. Finkelstein have secured research support from the Health Sciences Fund for this new area of study. In addition, the Veterans Administration has committed support for a summer, 1977 study of the relationship between laboratory technology, costs, and utilization. A proposal for further support of this research is pending with the National Institutes of Health.

Disease-occurrence modeling for management applications is another new area of research interest for which support is currently being sought. We hope, by fall, 1977, to have begun a modeling study of age-specific prevalence rates for over 100 diseases currently being observed among in-patients of the Veterans Administration health care system with an eye toward projecting future resource utilization. Dr. Finkelstein has assumed the lead for this research area.

Major efforts have been directed at moving the health management area toward having a critical mass of program, faculty, and supporting resources. Much time was spent during the year to develop comprehensive plans for launching a major research and teaching center on health care management, and substantial funding is being sought in order to implement

these plans. Two major steps toward this objective were achieved during 1976-77. A joint M. I. T. -Veterans Administration Center for Health Care Management was formed to advance initial Sloan School collaboration with the Boston Veterans Administration Hospital. Professor Roberts has been appointed Director of this joint research center, and he, Dean William F. Pounds, and Dr. Stearns are serving as M.I.T. representatives on the joint Advisory Board. Several meetings have been held and initial research proposals are in process.

The health policy and management programs at M. I. T. are also going to be included in Institute-wide plans to launch broader efforts relating to health care. Major capital funds have been raised during the year for a new building, in which space has been allocated for expanded programs in health management. A new joint biomedicine-management Ph. D. program is now under discussion for implementation as part of this major thrust by M. I. T.

As noted earlier, the Health Management Executive Development Program experienced its second year of operation in conjunction with the Sloan Fellows Program. As part of this program Dr. Stearns led in developing and implementing a year-long Seminar in Health Management, co-taught with Professors Harris and Roberts. This seminar brought to the Sloan School 20 leaders of medical schools and hospitals, government health agencies, and health related corporations for comparative assessments of management style and effectiveness. The seminar will be continued next year. A new group of Health Management Executives has been admitted for the 1977-78 program year and further program development is under way.

STAFF CHANGES AND PROMOTIONS

During the past year, Dr. Eli Shapiro returned to the Sloan School to assume the Alfred P. Sloan Professorship and rejoin the staff of the finance area. We appreciated his earlier major contributions to the School and look forward to equally vital years ahead.

Following the Institute designation of the position of Adjunct Professor, the Sloan School appointed two persons to that rank. Professor Banks, formerly of the Harvard Business School and Time, Inc., joined the policy and corporate strategy area as Adjunct Professor; and Richard Beckhard was promoted from Senior Lecturer to Adjunct Professor in the organization studies area.

Professor Hax was promoted to the rank of full Professor.

Dr. Terje Hansen, from the Norwegian School of Economics and Business Administration, served as Visiting Professor in the Management Science Group during the year; and Dr. Lipsky of the New York State School of Industrial and Labor Relations at Cornell University joined us as Visiting Associate Professor in the manpower and labor relations area. Professor Albert M. Marcotte of the Boston University School of Management was a Visiting Associate Professor with the Sloan School for the purpose of developing and conducting the computer simulated management game. Dr. Allen L. Sinai, Associate Professor of Economics at the University of Illinois at Chicago Circle, joined the faculty of the economics and finance area for the year as a Visiting Associate Professor.

Robert M. Alloway was promoted from Lecturer to Assistant Professor in the Management Science Group. Professor Alloway was on leave during the year to teach at the Stockholm School of Economics in Sweden. Dr. Barocci, who was also a Lecturer with the Sloan School, was promoted to Assistant Professor in the manpower and labor relations area. Two recent

Sloan School Ph.D. recipients were named to the staff as Assistant Professors. Professors Shaffer and Runge are both associated with the system dynamics area. Professor Michael F. Van Breda, formerly of the Graduate School of Business Administration, University of Witwatersrand, South Africa, joined the faculty of the management science area as an Assistant Professor. John E. Paap was named as an Instructor in the organization studies area during the 1976-77 academic year.

Harlan C. Meal, a senior staff member of Arthur D. Little, Inc., joined the management science staff as a Senior Lecturer part time. Benjamin C. Ball, Vice President for the Planning Research Department, Gulf Oil Corporation, took leave this year in order to assume the post of Visiting Senior Lecturer with the Sloan School and the Energy Laboratory. Richard A. MacKinnon was also a Visiting Senior Lecturer with the management science area. Mr. MacKinnon is the Manager of the Cambridge Scientific Center, IBM Corporation.

Drs. Gruber, McInnes, and Lawrence H. Linden were Lecturers in the management science area. Dr. Nina Rosoff, formerly of the University of New Hampshire's Whittemore School of Business and Economics, joined the organization studies area as a Lecturer.

Jerry C. Lamb worked as a Research Fellow with the Center for Information Systems Research. Mr. Lamb is a senior engineering research psychologist with the US Naval Underwater Systems Center. Christine V. Bullen, a 1976 Master's degree recipient from the Sloan School, also joined the CISR research staff.

Gay Van Ausdall was promoted to Administrative Assistant and Managing Editor of the Sloan Management Review.

We record with regret several departures from the Sloan School. Professor Paul W. MacAvoy joined the faculty of Yale University School of Organization and Management. Professor Bodie left to join the faculty of Boston University. Professor Sitikantha Mahapatra joined the faculty of Northeastern University.

This year, both Gertrude E. Burns and Professor Carroll L. Wilson announced their retirements, but Professor Wilson will remain on the staff part time in an emeritus role to continue his research in energy policy. We shall all miss Gertrude Burns' contribution and counsel as part of the School's administration.

We record with sorrow the death of our good friend and colleague, Professor Thomas M. Hill. Professor Hill had served on the Sloan faculty for 30 years as an educator, writer, and administrator. He is greatly missed.

WILLIAM F. POUNDS

School of Science

This was the second year in succession that a member of the faculty of the School of Science received the Nobel Prize. The 1976 Nobel Prize in Physics was awarded to Professor Samuel C. C. Ting of our Department of Physics and Professor Burton Richter of the Stanford Linear Accelerator Laboratory (SLAC). Professor Richter is an alumnus of the Department of Physics. The award was given "for their pioneering work in the discovery of a heavy elementary particle of a new kind." This particle was discovered by independent methods by Professor Ting and his Brookhaven-M. I. T. collaborators, including Associate Professor Ulrich Becker, Assistant Professor Min Chen, and others, and by Professor Richter and his colleagues Professor Martin Perl (SLAC), William Chinowsky, Gerson Goldhaber, and George Trilling (Lawrence Berkeley Laboratory). The particle was named J by the group headed by Professor Ting and ψ by the group headed by Professor Richter.

Academic Programs

In September 1976 the number of undergraduate majors in the School of Science was 1,033 compared with 1,113 the year before. The percentage of undergraduate majors in the School of Science was 31.7 percent in September 1976 compared with 34.1 percent in September 1975. The number of regular graduate students increased 1.9 percent (1,031 compared with 1,012 the year before).

Professor John M. Buchanan has served as faculty counselor for the Course XXV Interdisciplinary Science Program, and it has been a busy year with 16 undergraduate majors and 12 graduate students in Master's Programs. The Master's Program is on an experimental basis, and this spring it was reviewed by the Committee on Graduate School Policy. On May 18 the M. I. T. faculty voted to extend this experimental program until June 30, 1981. The purpose of the Course XXV Master's Program is to prepare students for positions in industry, government, education, and medicine where breadth as well as specialization is important and where more than a bachelor's degree is required. Specified programs are offered in Animal Cell Science, Science Education, and Environmental Science. In addition the Course XXV Committee will work with graduate students to develop individual Master's Programs with solid science cores.

RESEARCH

The research volume for the School is expected to be \$23,420,000 for fiscal year 1977 compared with \$21,275,000 for fiscal year 1976. (These figures do not include the research volume in the interdepartmental laboratories where School of Science faculty are involved.) This increase of 10 percent includes some real growth.

Four faculty members in the School of Science were heavily involved in the Viking experiments on Mars this year. Professor Klaus Biemann (Chemistry) was responsible for the mass spectrometer for the detection of organic matter, Professor Alexander Rich (Biology) was involved in the experiments to detect life, Professor M. Nafi Toksöz (Earth and Planetary Sciences) was responsible for the seismometer, and Professor Irwin I. Shapiro (Earth and Planetary Sciences) performed transmission experiments to test the theory of relativity.

During the year Professor Jule Charney began steps toward the development of a Center for Climate Research to be operated jointly by M. I. T. and Harvard.

Professor Herbert S. Bridge has been appointed Acting Director of the George R. Wallace, Jr., Astrophysical Observatory and Chairman of the Steering Committee to replace the former director, Professor Thomas B. McCord, who has moved to the Institute of Astronomy, University of Hawaii. The two telescopes of the Observatory have been heavily used both for research and instruction, and have been very useful for testing new instruments for later use at major observing facilities around the world.

This year involved a great deal of discussion of issues of recombinant DNA Research and the development of new arrangements to provide safe conditions for this research at M. I. T. The National Institutes of Health (NIH) Guidelines for Recombinant DNA Research were published in the Federal Register on June 23, 1976. It was just at this time that Mayor Alfred E. Vellucci and the City Council of Cambridge had become aware of Harvard's plans to build a so-called P-3 laboratory in the Biological Laboratories to carry out recombinant DNA experiments according to the NIH Guidelines. M. I. T. had a laboratory of this type in the Center for Cancer Research which, after some small modifications, was certified by the M. I. T. Assessment of Biohazards Committee as satisfying the NIH requirements for a P-3 laboratory. On July 7, 1977, the City Council passed a three-month "good faith" moratorium on P-3 recombinant DNA experiments in the City of Cambridge, and this moratorium was later extended for another three months so that a Cambridge Laboratory Experimentation Review Board, appointed by the City Manager, could study the situation and make recommendations to the City Council. M. I. T. cooperated in this moratorium and in the discussions with the City Council and the Cambridge Laboratory Experimentation Review Board. In January this Board recommended unanimously that P-3 recombinant DNA experiments could go on in Cambridge if certain precautions in addition to those in the NIH Guidelines were taken. Experiments of this type have been carried out during spring term.

The Center for Cancer Research, the Department of Biology, and the Department of Nutrition and Food Science all have safety committees involving faculty, students, and employees of the laboratories. These committees have met regularly to discuss potential hazards and actions to be taken. They also have served to increase the awareness of everyone in the area with the importance of safety precautions.

FACULTY

This spring Professor Frank Press was appointed by President Carter to be Director of the Office of Science and Technology Policy and the President's Science Advisor. Thus Professor Press follows James R. Killian, Jr., the first presidential Science Advisor, who served President Eisenhower, and Jerome B. Wiesner, President Kennedy's Science Advisor, in this important post. Professor Press had been Head of the Department of Earth and Planetary Sciences since 1965 and Robert R. Shrock Professor of Earth and Planetary Sciences since 1970. With his leadership the Department has grown and prospered. Professor Press has played an important role in the M. I. T. community in other ways -- he has been responsible for the Joint Doctoral Program with the Woods Hole Oceanographic Institution, last academic year he was the James R. Killian, Jr. Lecturer, and this year he chaired the Committee on M. I. T. Research Structure. Professor Carl I. Wunsch has been appointed Acting Head of the Department of Earth and Planetary Sciences. Professor Wunsch has been Cecil and Ida Green Professor of Physical Oceanography since October 1, 1976. His research interests have included the study of internal waves, tides, mixing processes and dynamics of mid-latitude and equatorial circulation. In 1976 Professor Wunsch received the Texas Instruments Foundation Founders Prize. A departmental search committee for a new Department Head has been established and is chaired by Professor Stanley R. Hart.

Professor Gene M. Brown will succeed Professor Boris Magasanik as Head of the Department of Biology, effective July 1, 1977. Professor Magasanik has served as Head for 10 years, and they have been years of increasing numbers of biology students, both undergraduate and graduate, and increasing distinction of the faculty of the Department. Three members of the faculty are Nobel Laureates: Professors David Baltimore, H. Gobind Khorana, and Salvador E. Luria. With Professor Magasanik's leadership, the Department has cooperated in the establishment of the Center for Cancer Research, directed by Professor Luria, and the Harvard-M.I.T. Program in Health Sciences and Technology, directed by Professor Irving M. London. While Head of the Department, Professor Magasanik has also maintained an active research program. Professor Brown has served as Associate Department Head these past five years and as Deputy Department Head before that. Professor Malcolm Geffer will serve as Executive Officer.

Professor Edward N. Lorenz will become Head of the Department of Meteorology on July 1, 1977, succeeding Professor Charney, who has been Department Head since 1974. During his term Professor Charney has added a number of new faculty members and has developed new research activities.

Professor Willem V. Malkus will succeed Professor Daniel J. Kleitman as Chairman of the Applied Mathematics Committee July 1, 1977.

Four members of the faculty of the School were elected to the National Academy of Sciences in April of this year: Professors Ting, Michael Artin (Mathematics), Louis N. Howard (Mathematics), and Gerald N. Wogan (Nutrition and Food Science). Two members of the School were elected to the American Academy of Arts and Sciences: Professors Jeffrey Goldstone (Physics) and Lee Grodzins (Physics).

Four members of the faculty were honored this year by the award of named professorships. Professor Ting became the Thomas Dudley Cabot Institute Professor. Professors Wunsch, William F. Brace (Earth and Planetary Sciences), and Herman Feshbach (Physics), were named Cecil and Ida Green Professors. The Greens have been very generous to M.I.T. and had earlier created the Robert R. Shrock Professorship, held by Professor Frank Press; the Cecil and Ida Green Professorship of Education, held by Professor Seymour A. Papert (Education Division); and the Cecil H. Green Professorship of Electrical Engineering, held by Professor Alan V. Oppenheim.

Professors Sidney M. Hecht of the Department of Chemistry and Michael C. Archer of the Department of Nutrition and Food Science received NIH Career Development Awards.

Professor Rich became a member of the National Science Board.

Professor Feshbach is serving as Chairman of the Panel on Public Affairs of the American Physical Society, 1976-78.

Professors Bernard S. Gould (Biology), Patrick M. Hurley (Earth and Planetary Sciences), John C. Sheehan (Chemistry), and Clark C. Stephenson (Chemistry) will retire at the end of this year. Their cumulative service to M.I.T. is 151 years. Professor Gould came to the Institute in 1934 as an Instructor and was appointed Assistant Professor in 1937. In recent years he has played an important role in the establishment of the Office for Preprofessional Advising and Education and the counseling of premedical students. Professor Hurley came to the Institute as a Research Associate in 1940 and was appointed Assistant Professor in 1946. He has been the leader in the area of mineral resources and the applications of thermodynamics and isotope techniques to understanding the development of the earth. Professor Sheehan came to the Institute in 1946 as Assistant Professor. He has made many contributions to synthetic organic chemistry, including methods for making various types of penicillin which are used commercially and have provided patent income to the Institute for a number of years. Professor Stephenson came to the Institute in 1937 as an Instructor

and was appointed Assistant Professor in 1942. He is widely regarded as an outstanding teacher of chemical thermodynamics, and through his efforts, Chemistry 5.60 Chemical Thermodynamics has an outstanding reputation and attracts many students from a variety of departments.

During the year the departments in the School reached outside to hire two new faculty members at the rank of Professor. Professor Miklos Porkolab of Princeton University accepted a professorship in the Department of Physics, and Professor Satoru Masamune of the University of Alberta accepted a professorship in the Department of Chemistry.

The School lost two faculty members to other institutions during the year: Professor K. Barry Sharpless (Chemistry) moved to Stanford University, and Professor Thomas B. McCord (Earth and Planetary Sciences) moved to the Institute of Astronomy at the University of Hawaii.

ROBERT A. ALBERTY

Department of Biology

During the year, 393 undergraduate students concentrated in the life sciences and 158 were awarded the S. B. in this field; the previous year's figures were 397 and 147, respectively. Between July 1, 1976, and June 30, 1977, seven Ph. D. s and three S. M. s were awarded in Biology. Two Ph. D. s in Biological Oceanography were awarded under the Joint Program with the Woods Hole Oceanographic Institution. There were 110 graduate students in the Department during the past year. We have admitted 18 new graduate students to our graduate program for the academic year 1977-78. Of the 18 new students, one has received the very competitive National Science Foundation (NSF) Fellowship and one has received The Danforth Foundation Fellowship. Approximately 39 undergraduate students participated in research programs during the regular academic year. Professor David E. Housman has been coordinator of our undergraduate research program.

The Third John L. Asinari Awards, in memory of John L. Asinari, Class of 1975, for outstanding research by undergraduates in the life sciences were given to John J. Krolewski of Coventry, Rhode Island, a senior in the Department of Nutrition and Food Science, and Marc S. Levin of New Rochelle, New York, a senior in Biology. Honorable mention went to David J. Julius of Brooklyn, New York, a senior in Biology, Deborah Rubin of Brooklyn, New York, and Thomas R. Skopek of Stafford Springs, Connecticut, both seniors in Nutrition and Food Science.

RESEARCH

The research of members of the Department's faculty, research associates, research fellows, and graduate students is described in a publication entitled "Research Summaries." It is available at departmental headquarters.

CURRICULUM

In the course of the previous year, a careful evaluation of our undergraduate program had been undertaken by a committee chaired by Professor John E. Holt. The changes recommended by the committee and approved by the faculty have become effective during this academic year. The major change is to make subject 7.03 Genetics an absolute requirement in addition to subject 7.05 General Biochemistry. The more advanced undergraduate subjects are then taken by students who have been introduced to the fundamental subjects biochemistry and genetics.

FACULTY

Assistant Professors Paul D. Gottlieb, Nancy H. Hopkins, and Bonnie M. Tyler were promoted to Associate Professors effective July 1, 1977. Associate Professor Mary Lou Pardue was awarded tenure to become effective July 1, 1978. Professor Michael J. Bevan was appointed Assistant Professor of Biology effective January 1, 1977. Professor Bevan received his Ph. D. from the National Institute for Medical Research in London in 1972, and has since that time been a Postdoctoral Fellow and Senior Research Associate in the Developmental Biology Laboratories, The Salk Institute for Biological Studies, La Jolla, California. Professor Maurice S. Fox has been on sabbatical leave during the year at the Harvard School of Public Health. Professor Bernard S. Gould has retired after reaching the mandatory retirement age of 65. He continues to serve as Professor Emeritus and Senior Lecturer. As in the past, Professor Gould will coordinate the undergraduate program as Undergraduate Registration Officer and will continue to serve as Chairman of the Committee on the Use of Humans as Experimental Subjects and Chairman of the Premedical Advisory Council.

Professor Boris Magasanik has ended his second five-year term as Head of the Department of Biology and will continue his teaching and research activities. He is succeeded by Professor Gene M. Brown, a distinguished biochemist, who has served the Department during the last 10 years first as Executive Officer and then as Associate Department Head. Professor Malcolm L. Geftter will become Executive Officer of the Department.

It seems appropriate to comment briefly at this time on the changes that have taken place in the Department during the last 10 years. The most easily observed change is growth. During this period the number of undergraduate majors in Life Sciences increased from little over 100 to almost 400. The increase in the number of graduate students was more modest from approximately 70 to 120. The faculty increased from 28 to 42. The actual change in the composition of the departmental faculty is much greater: 28 of our present faculty members have joined the Department in the last 10 years.

The growth of the Department has been paralleled by an increase in the quality and scope of our research and teaching. Distinguished prizes are often used as indicators of quality: during the last 10 years two members of our Department have been awarded the Nobel Prize and a third Nobel Laureate has joined the Department. We have retained our excellent standing in biochemistry and molecular genetics, earned earlier than 10 years ago, and have become leaders in microbiology, cell biology, developmental biology, and immunology.

The excellence of the Department facilitated the creation of the Center for Cancer Research and of the Program in Health Sciences and Technology. In turn these programs, and in particular the Center for Cancer Research, have been instrumental in the growth of the Department and contribute to its vigorous intellectual climate.

The great emphasis on research of high quality has not deflected us from our commitment to graduate and undergraduate education. It is particularly gratifying that a majority of the Department members most active in research have also made major contributions to our undergraduate program. It is generally agreed that the curriculum developed in the last 10 years, in particular the laboratory subjects, offer students a unique opportunity to acquire an exceptional background for continuing graduate study in biology or medicine. The excellent success of our students to gain admission to the most prestigious medical and graduate schools provides evidence for the success of this program.

BORIS MAGASANIK

Department of Chemistry

Bachelor of Science degrees in chemistry this year were awarded to 37 undergraduates: one in September, seven in February, and 29 in June. Most of the graduates will be attending graduate school in chemistry, medicine, or related areas, or have been employed by industry. The degree of Master of Science was awarded to 10 candidates: six in September, one in February, and three in June. A total of 37 Ph.D.s was awarded to 16 candidates in September, nine in February, and 12 in June. To date, 1,495 Ph.D. degrees and 368 Master's degrees have been awarded by the Department.

RESEARCH

The Department has continued its outstanding and active research program during the past year. The research is in a variety of fields, both within chemistry and with associated disciplines. The following is a description of a few representative research programs which are in progress in the Department.

Research efforts in Professor Glenn A. Berchtold's laboratory have concentrated on understanding the chemistry of arene oxides and on the synthesis of substances that are metabolic intermediates in the biosynthesis of aromatic amino acids and growth factors in bacteria, fungi, and higher plants.

Arene oxides are the initial metabolic intermediate in the detoxification of aromatic hydrocarbons in mammals. In the normal course of events they undergo spontaneous isomerization to phenolic derivatives or react with water or glutathione to afford substances that are excreted, but it appears also that they undergo other reactions that ultimately lead to the toxic, carcinogenic and mutagenic effects ascribed to aromatic hydrocarbons in mammals. Because of the importance of arene oxides in biological systems, detailed studies of their chemical reactivity have been carried out in order to understand their reactivity in biological systems. The spontaneous isomerization of benzene oxide, the parent system, to phenol proceeds via a cationic intermediate that has been prepared as a metal-stabilized complex; and the chemistry of this interesting complex is under investigation.

The biosynthesis of aromatic amino acids and growth factors in bacteria, fungi, and higher plants occurs via dihydroaromatic substances with heteroatom substituents on the saturated carbon atoms. Few procedures have been available for the laboratory synthesis of these substances because of their tendency to aromatize under a variety of conditions. Recent

efforts have resulted in the development of new methods to prepare these substances, and the procedures have been applied to the synthesis of specific materials that are metabolic intermediates. Current studies are concerned with the preparation of structural analogs of certain metabolic intermediates in a search for substances that will undergo enzyme-catalyzed reaction by enzymes that effect reaction of the normal intermediates and produce reactive materials that will form a covalent bond at the active site of the enzyme. Such substances will be useful for studies of enzyme properties and might serve a useful purpose as antibiotics, antifungal agents or plant growth regulators.

During the past year, much of the research effort in Professor Klaus Biemann's group has been devoted to the activities connected with the Viking Mission to Mars. A miniaturized gas chromatograph-mass spectrometer system had been deployed on the surface of the planet at two locations by the Viking 1 and 2 landers. It served two purposes: to repeatedly analyze the martian atmosphere near the surface of the planet and to search for organic compounds in the surface material. The first objective resulted in the detection of minor and trace constituents, such as nitrogen, argon, krypton, xenon, and finally neon and the determination of their isotopic abundances. The organic portion of the experiment demonstrated the virtual absence of organic compounds in the surface material of the planet. These results have important implications for our understanding of the history of the planet and its atmosphere as well as the chemical processes which can and cannot occur on the surface. Finally, the demonstration that there is no accumulation of organic material has an important impact on the question of existence of living systems on the planet and was essential for the interpretation of the Viking biology results.

During this time, research related to our major area of interest, the determination of the structure of complex organic molecules by mass spectrometry, has continued. The development of a mass spectrometric technique for the determination of the primary structure of large peptides and proteins had reached a stage where one could attempt to successfully apply it to naturally occurring molecules of this type and of yet unknown structure. The complete amino acid sequence of the sweet tasting protein Monellin was determined by this technique. It was found to consist of two subunits of 44 and 50 amino acids each, the sequence of which was deduced from the mass spectrometric analysis of the complex mixtures of small peptides obtained by partial chemical or enzymatic degradation of the separated subunits.

Using the same technique in collaboration with Professor Ptashne at the Biological Laboratories, Harvard University, who used the Edman degradation, the two techniques were combined to determine the primary structure of the " λ -repressor" which consists of 240 amino acids. By combining the results obtained by these two techniques carried out simultaneously, one was able to deduce the sequence of this protein in less than a year's time, and with a degree of redundancy in information that makes the results more reliable than using one technique alone.

With the acquisition of a new high resolution mass spectrometer, capable of field desorption of organic substances of low volatility, the capability of our laboratory has been substantially increased. Experimental techniques for the determination of high resolution mass spectra obtained in this fashion have been developed and computer based methods for the processing and interpretation of these data have been and are still being developed. It promises to be a very powerful tool for the determination of the structure of biologically important molecules.

Professor Alan Davison's research efforts in inorganic chemistry have been centered around two diverse areas: a) transition metal organometallic chemistry and b) technetium chemistry.

Transition Metal Organometallic Chemistry. Synthetic methods to make bifunctional cobalt-cinium compounds with a variety of donor groups have been developed. These compounds function as a new class of bidentate ligands towards metals in a variety of oxidation states.

In work that is synthetically closely related to the study of metallocenes, work is continuing on metal fulvalene complexes. Simple bisfulvalene dimetals as well as oligomeric compounds have been characterized. They show interesting oxidation-reduction behavior and give rise to well-characterized "mixed valent" species. Some of the metal fulvalene systems show prospects for forming new organic metals.

Collaborative studies with Professors David Adler (Electrical Engineering and Computer Science) and Keith Johnson (Materials Science and Engineering) are being undertaken to understand the electronic structure and electrical behavior of these new materials.

In a different area, the chemistry and the interrelationships of monohapto acetylenic, vinylidene, vinyl, carbenoid, acyl, alkyl and carbonyl complexes have been developed. This has enabled viable synthetic transformations between these derivatives to be performed. This work has had the goal that efforts must be made to modify (by synthetic transformation) the alpha oxygen functionality such that it can become a good leaving group under reductive conditions to generate metal alkyls. A detailed knowledge of these systems is a necessary first step to developing a rational approach to the design of homogeneous transition metal catalysts for the reduction of carbon monoxide to useful organic molecules such as alkanes, ketones, alcohols, etc.

Technetium Chemistry. Despite the success in the development and the routine use of the gamma emitting metastable isotope of technetium in a variety of radiopharmaceuticals (e. g., lung scanning, bone scanning, blood pool labeling, etc.) the chemistry of the man-made element technetium is virtually unexplored. The commonly occurring isotope of technetium is relatively long-lived (2.5×10^5 years, a weak beta emitter) and is in principle a readily available reactor product. It is now more abundant than its natural congener rhenium. In the last year a new program of systematic research into the chemistry of technetium has been initiated. From its position in the periodic table (in the same group as and lying below manganese and above rhenium) it can be safely assumed that the chemistry will be among the most diverse found for transitional metals. Initial studies have been directed towards 1) the preparation and use in synthesis of organic solvent soluble tetraalkylammonium hexahalometalates in the formal oxidation state (IV), which have proved to be valuable for non-aqueous synthesis of complexes in oxidation states (IV), (III), (II) and (I); 2) the preparation of complexes from ligands with sulfur donor atoms which bond to the metal. The starting material for these studies are the readily available pertechnetate salts in oxidation state (VII). It has proved possible to isolate crystalline complexes with a variety of such ligands (e. g., dithiolates, thiourea, dithiophosphinates, thio-glycollic acid, etc.).

The chemistry of these new materials is under investigation. Because it is expected that technetium chemistry will resemble that of rhenium closely, comparative studies on rhenium chemistry are being simultaneously performed. These studies already have shown that technetium shows much greater tendency to bind to sulfur than does rhenium.

The research of Professor Robert W. Field is focused on three related problems:

Spectroscopic Characterization of Low Lying Electronic States. New tunable laser techniques are used to simplify the assignment of extremely complex spectra and to gain access to normally inaccessible states. Of particular interest are weakly radiating levels, which often act as energy reservoirs in flames, and levels near dissociation. Chief among the techniques being developed are Optical-Optical Double Resonance and Optically Pumped Lasers. Double resonance involves sequential excitation of a molecule by absorption of two laser photons. This two-step process permits spectral simplification as well as bending of the usual one-photon selection rules. The optically pumped laser experiments utilize one laser to excite molecules while inside a second laser resonator, thereby causing the optically pumped molecules to lase. Such a technique allows observation, assignment, and frequency measurement of transitions that are undetectable in spontaneous fluorescence.

Energy Transfer Superhighways. Little is known about how the energy released in chemical reactions is partitioned among rotation, vibration, and electronic internal modes or about how this nascent distribution relaxes. Numerous systems are known in which population is collisionally transferred from initial to intermediate to final excited state without significant loss. Double resonance provides diagnostics for monitoring populations in non-radiating states and optically pumped lasers provide a way of preparing large populations in single and selectable metastable levels.

Analysis of Spectroscopic Perturbations. The electronic spectra of small molecules invariably exhibit certain frequency and intensity irregularities. These perturbations often provide clues to the existence of previously unknown excited states. They also turn out to be the key to rapid collision induced transfer between electronic states. Double resonance techniques are ideally suited for analyzing perturbations and thus the coupling between two states. They are equally well suited for monitoring the flow of population from one state to another via the perturbed levels. A monograph on analysis and practical applications of perturbations is being prepared jointly with Dr. H. Lefebvre-Brion of the Laboratoire de Photophysique Moleculaire at Orsay, France.

The research of Professor Robert J. Silbey's group has been concerned with the interaction between a molecule and a solid surface. This interaction is an important component of a number of unresolved problems in physical chemistry. For example, the primary step in heterogeneous catalysis is the adsorption and dissociation of a molecule on the catalyst surface. In the last year, we have been studying the interaction between molecules and metal surfaces by a variety of theoretical methods. We have examined a large range of interaction strengths, from the weak adsorption of rare gas atoms on metals to the very strong adsorption of hydrogen on copper. In the following a short statement of our findings is given.

Recent work has suggested that the cleavage of hydrogen molecules on platinum requires a rough or stepped surface. In addition, this process on copper surfaces proceeds with an activation energy that varies from face to face. Our group has recently been trying to understand these processes theoretically. Using semi-empirical quantum chemical methods, we have studied the copper surface/hydrogen molecule interaction and found that the interaction and activation energy for dissociation can be understood using a simple model. We find good agreement between theory and experiment for copper surfaces. In addition, a detailed study of rough surfaces predicts that hydrogen atoms will adsorb preferentially at steps and notches in the surface, and that the activation energy for dissociation of a hydrogen molecule at such sites is lower than on smooth surfaces. Thus, we find qualitative agreement with the idea that rough or stepped surfaces are important for catalytic reactions.

In addition to this, we have been studying the weak physical adsorption of rare gas atoms on metal surfaces using a very different theoretical formulation. The energy of a system of electrons and fixed nuclei can be written as a functional of the electron density. Unfortunately, the form of this functional is known only for the case of the homogeneous electron gas. By approximating the energy of a rare gas atom near a metal surface by the homogeneous electron gas function and by using exact electron densities for the atom and surface, we have calculated the interaction energy between them. We find remarkably good agreement with experimental values in the cases for which such values are known. This method, which has the advantages of simplicity and accuracy, can be used for more complex systems as well, if there is only a weak bond formed.

Personnel

Two members of the faculty retired, Professors John C. Sheehan after 31 years and Clark C. Stephenson after 40 years in the Department of Chemistry.

Professors Silbey and Mark S. Wrighton will be promoted to the rank of Full Professor.

Dr. Rick L. Danheiser will join the staff as an Assistant Professor in Organic Chemistry.

Professor K. Barry Sharpless left the Department to accept a position at Stanford University.

We were saddened by the death of Professor Leicester F. Hamilton on December 22, 1976.

Professor Biemann was awarded by NASA the Exceptional Scientific Achievement Medal in recognition of exceptional contributions as leader of the Viking Molecular Analysis investigation in the field of planetary chemistry, while conducting the first on-site chemical analysis of the surface of Mars. The Austrian Society for Micro Chemistry and Analytical Chemistry awarded him The Fritz Pregl Medal in recognition of contributions to the field of mass spectrometry.

Visiting faculty and scientists were as follows: Sergio Alumni, University of Perugia, Italy; Pierre Borgeat, Laval University, Canada; Cornelius A. DeLange, Free University Amsterdam, Holland; Henri L. Dubost, University of Paris, France; Gad Gorodetsky, Ben Gurion University, Israel; Allan R. Gregory, Australian National University, Australia; Juergen H. Hahn, Max-Planck Institut, Mainz, Germany; Peter Holl, Technische Universitaet, Munich, Germany; Nicolaas G. van Kampen, University of Leiden, Holland; Ki-Hyup Kim, Seoul National University, Korea; Raphael D. Levine, Hebrew University, Jerusalem, Israel; Esteban Martina-Bogetto, University of Mexico in Mexico City; Halina Miller-Podraza, Warsaw University, Poland; Louis Nadjo, University of Paris, France; James A. Reiss, La Trobe University, Victoria, Australia.

The Department was privileged to sponsor a series of lectures provided by the Arthur D. Little, Karl Pfister, and T. Y. Shen Visiting Professorships. Arthur D. Little Visiting Professor Henry Taube of Stanford University lectured on the following topics: "Intramolecular Electron Transfer," "Mixed Valence Molecules," and "Back-bonding in Classical Complexes." Arthur D. Little Visiting Professor Joseph Chatt of the University of Sussex gave three lectures: "Nitrogen Fixation," "The Reactions of Ligating Dinitrogen," and "The Charge Distribution in Complex Compounds." Karl Pfister Visiting Professor Satoru Masamune of the University of Alberta gave two lectures: "Cyclobutadiene," and "Macrolide Syntheses." Dr. Bengt Samuelsson of the Karolinska Institutet, Stockholm was the T. Y. Shen Visiting Professor. His lectures were "Recent Progress in the Chemistry and Biology of Prostaglandins and Thromboxanes I - III."

JOHN M. DEUTCH

Department of Earth and Planetary Sciences

In the past year, 126 full-time graduate students were registered in the Department of Earth and Planetary Sciences. Of these, 38 were students in the M.I.T.-WHOI Joint Program in oceanography; there were 71 undergraduates. The following degrees were conferred: 17 S.B.s, 15 S.M.s, and 16 Ph.D.s, 6 of which were conferred jointly with Woods Hole Oceanographic Institution. Our graduate students seem to be having no problem in finding positions either in industry or university settings. We supported 89 undergraduates on the student payroll this year.

Honors and Awards

Two new Cecil and Ida Green Professorships given to the Department through the generosity of the Greens were awarded to Professors Carl Wunsch and William F. Brace. Professor M. Nafi Toksöz received the NASA Exceptional Scientific Achievement medal.

Curriculum

The Department offered three undergraduate seminars: Professor John Edmond on the chemistry of Massachusetts environmental waters, Professors Peter Molnar and Tanya Atwater on plate tectonics and continental drift, and Dr. Michael Gaffey, Sponsored Research Staff, on an introduction to space colonization, which drew an amazing crowd of 63 students. All three were well received.

The first year of our field geology sequence was quite successful, as 21 of our students made the trip to the Big Bend region of Texas during January Independent Activities Period, following it with a report written in spring term. Professors John S. Dickey, Stanley R. Hart, and B. Clark Burchfiel, as well as three graduate teaching assistants, Karleen Davis, Marc Loiselle, and Gerald LaTorraca, participated in all or part of the field trip.

Professor Hart offered an undergraduate introductory geochemistry sequence for the first time this year, providing a valuable year-long overview to advanced undergraduates and first-year graduate students.

On the graduate level, a new seismology seminar has been added, taught by the geophysics/seismology faculty. Professors Burchfiel and Molnar were able to combine forces in a course on world regional tectonics which had good enrollment. Dr. Albert W. Bally, as Crosby Visiting Professor, brought in his expertise as a staff geologist for Shell Oil Company and presented a concentrated course on petroleum geology to a diverse group of juniors, seniors, and graduate students from five departments for the first three and a half months of spring term.

RESEARCH

Professor Toksöz and his group have been continuing their studies of the crustal structure and earthquake risk in New England. They are now completing a seismic network covering eastern New England from New Hampshire to Cape Cod. The George R. Wallace, Jr. Geophysical Observatory is the center of this network. Analysis of New England seismicity reveals that the region was more active in the seventeenth and eighteenth centuries than it has been in the last 100 years. Studies of the seismicity of Mars are now possible for the first time with the deployment of a seismometer there from the Viking space craft. Professor Toksöz, a member of the Viking science team, now receives data from three astronomical bodies: the earth, the moon, and Mars. Although information from Mars is still preliminary, Professor Toksöz has found it to be an interesting planet with seismicity intermediate between the earth and the moon. That is, there are fewer Marsquakes than earthquakes. Professor Kei Aki has succeeded for the first time in determining the basic earthquake source parameters; that is, the seismic moment tensor by using linear inversions of surface wave spectra. This new method is about 100 times faster than conventional methods and eliminates the need for an initial model. In addition, a new earthquake source model was introduced involving fault planes with distributed barriers. This model may play an important role in linking future earthquake motion on a geologic fault with detailed maps of past fault breaks.

The relationship between oceanic earthquakes and the mechanical and thermal structure of seafloor spreading centers has been studied by Professor Sean Solomon and his colleagues. The largest earthquakes on ridge axes show a systematic decrease in seismic moment with spreading rate, a relationship that can be explained quantitatively if an isotherm limits the depth to which young oceanic lithosphere fails seismically and if the largest ridge crest events occur 10 to 20 kilometers off axis. The maximum size of earthquakes on oceanic transform faults increases with offset and decreases with spreading rate. Systematic inversion of earthquake data on 60 oceanic transforms supports the hypothesis that the depth to an isotherm controls the fault area susceptible to seismic failure and gives a value for the limiting temperature. During an oceanographic expedition to the triple junction in the central Indian Ocean last year, an ocean bottom seismometer was dropped near the junction to investigate whether such a region is different from more normal spreading centers. The numerous microearthquakes observed, however, have parameters indistinguishable from those on other ridgetransform systems.

Processes of transport of loose sediment by fluid flows are being dynamically modeled by Professor John Southard in laboratory flume experiments. Scaling considerations indicate that the use of quartz sand and hot water to model transport of quartz sand by natural cold-water flows provides flow variables in naturally important ranges. As a test, properly scaled runs were made in the ripple regime, with water viscosity controlled by temperature. Frequency distributions of ripple height, spacing, and migration rate were determined for a very large number of ripples; the test for scaling is whether the two curves for each of these variables coincide when the appropriate scale factor is applied. The results indicate that modeling is feasible. The technique will be extremely valuable in the study of transport rates and bed geometries in natural sediment-transporting flows because scaled-up laboratory flume experiments are well into the range of natural tidal currents and rivers.

In order to study the effect of microfractures on the physical properties of rocks, Professor Gene Simmons and his group have developed a technique called differential strain analysis. This technique permits the precise measurement of rock strain under hydrostatic pressure allowing the fracture content of rock to be measured, as well as giving information as to fracture shape and distribution. Specifically, a number of techniques are being used to determine the effect of microfractures in geothermal areas in "self-sealing" geothermal systems. Transport of hot fluids is often dependent on the fracture content of the rocks. Simmons' group has found, however, that physical properties of the lower crust behave differently in situ than in the laboratory. For example, in the laboratory, microfractures can be closed mechanically, but not electrically. In the lower crust, however, cracks will be closed in both respects so that in situ resistivities will be much higher than the measured laboratory values under similar pressure-temperature conditions.

Professor Theodore Madden has continued the development of a general modeling method which should have many applications in rock physics modeling and related boundary value problems. The method, a form of multiple scale analysis, consists of a sequence of embedded networks. The first applications have been made to study flow properties in rocks in the geometric mean mixing law of heterogeneous media. Reasonable predictions of rock flow properties have been obtained given the distribution of crack and pore lengths and widths. The commonly observed geometric mean mixing law was shown to be due to wide distribution of shapes of the various phases making up the medium.

The important problem of understanding the flow of rocks under stress and high temperature has been continued by Professor Christopher Goetze. In particular, he has been studying the plastic flow of olivine under conditions of stress, temperature and grain size not previously explored. Hot hardness measurements have duplicated previous polycrystalline data below 800° C and cover the previously unexplored region between 800° C and room temperature. These high stress measurements are important because stresses which occur in the earth straddle two different mechanisms of behavior, and these are the first measurements to give a good picture of the high stress mechanism. In another series of experiments, aggregates of olivine covering a wide range in grain size have been pressed. A grain size sensitive field of deformation predicted long ago on the basis of tests on other materials was found to dominate the behavior of the finer grained samples. Professor Goetze is pursuing this result in a number of minerals now because it is believed from field evidence to weaken shear zones of high stress in the earth.

Professors Dickey and Fred Frey, with their colleagues, have been studying the accessible piece of upper mantle to be found in the Serrania de la Ronda peridotite body in Southern Spain. This peridotite with its included mafic layers is a piece of upper mantle that underwent partial fusion prior to its emplacement in the crust. These studies are providing information about mantle tectonics and the generation of partial melts within the upper mantle. The fieldwork produces models showing how specific parts of the deep lithosphere moved in thermodynamic terms, along the boundary between impinging tectonic plates. Professor Frey, working with basalts recovered from the Indian Ocean seafloor by the deep sea drilling project, has been examining the tectonic development of major features of the Indian Ocean. The aseismic ninety

east ridge appears to be constructed of volcanic products similar to the St. Paul-Amsterdam Island complex in the Indian Ocean whereas most of the deep Indian Ocean seafloor is composed of tholeiitic basalts similar to that formed at moderate Indian Ocean ridges.

Working with Dr. Chris Brooks of the University of Montreal, Professor Hart has measured strontium isotope abundances on a number of very pure clinopyroxene samples in 2.7 billion-year old ultramafic rocks of the precambrian shield in Canada. Resulting values provide the best estimate so far for the strontium isotope ratio of early precambrian mantle. The result is consistent with a closed system evolution of the earth's mantle from 4.5 b.y. to 1.8 b.y. followed by development of major mantle heterogeneities which have persisted to the present.

Using two separate methods of radiometric dating, Professor Patrick M. Hurley and his student, Carla Montgomery, have discovered a section of ancient rocks in Venezuela comparable in age to the oldest known rocks on earth -- about 3.7 b.y. They were able to achieve this result despite the intense effects of a high grade metamorphism about 2 billion years ago.

Professor Edmond, working with colleagues from the Woods Hole Oceanographic Institution and Oregon State University, made the exciting discovery of the first hydrothermal field to be found in the deep sea. The observations were made first hand from the research submarine, Alvin. The hydrothermal fields are located at the zero age axis of the Galapagos spreading center. The fields are presumably produced by convection of water which penetrates into the cooling, newly intruded crustal material along cracks and joints in the cold basalt. It is presumed that this is a global phenomenon. Geophysical estimates of the heat transported by the convected seawater indicate that the water flow is about one percent of that of the earth's rivers. The chemistry of the hot spring waters is found to be drastically altered from that of the original seawater by high temperature reactions with the basalt. It is strongly enriched in manganese, iron, silica, and barium and is probably the primary source of the metals observed to be enriched at oceanic ridge crests. For reasons that are not yet understood, the fields of hot springs act as extremely favorable biological environments, with clams over a foot long choking some vents and abundant anemones, limpets, fish, crabs, etc., found in striking contrast to the barren, inactive seafloor.

In other work, Professor Edmond has successfully completed his second expedition to the Amazon basin. He has found reported in the older literature widespread occurrence of salt diapirs in the eastern Andes. The Indian languages contain a host of terms to describe the features produced by salt intrusions. The salt is mined extensively and in one spectacular location -- four cliffs about 300 meters high along the front and nine kilometers long on the Huallaga, a major Amazonian tributary. The effect on the water chemistry is profound. It would appear that over half the sodium and chloride transported by the Amazon to the Atlantic is derived from sources of this kind rather than the classically suggested primary reactions between rain and ground waters and hard rock.

Professor John Sclater undertook a cruise on the Argentine Research Vessel, ISLAS ORCADAS, during the austral summer of 1976. The primary objective of the cruise was to map fracture zones and magnetic anomalies east of the Bouvet Triple Junction which would help in reconstructing the history of past motion between Africa and Antarctica. Four fracture zones, one of which stretches as a major ridge with relief over 3 kilometers, were discovered. Some dredging was carried out in the fracture zones with recovery of rock that is thought to represent the upper mantle. Ridge arcs showed a large magnetic signature, but older anomalies have been difficult to identify. Using the fracture zones and other data in the Indian Ocean as constraints, a speculative history of the evolution of Southwest Indian Ridge has been developed. In another study of ridges, Professor Sclater, working with Dr. Barry Parsons, Research Associate, is continuing to study the relationship between the depth of water and the age of the seafloor. Different models yield different relationships. Actual field data can be inverted to give parameters of the different models. The depth of water seems, initially, to increase with a linear dependence on \sqrt{t} , where t is the age of the

ocean floor; but between 60 and 80 million years before the present, the variation of depth with age departs from this simple relationship. This departure can then be used to distinguish the models.

The now highly important problem of the relationship between convection within the earth and the motion of the spreading plates at the surface of the earth has been the subject of work by Drs. Parsons and Dan P. MacKenzie, Visiting Professor from Cambridge University. In their model, the convection driving the plates becomes unstable in a certain parameter range; this instability coincides with the breakdown of the dependence of the depth of the ocean floor on the \sqrt{t} . This instability has been tested in two different laboratory experiments which illustrate a possible form for an instability with dense material breaking away from the base of the plate and being replaced by hotter material from below.

The planetary science group in the Department under Professor Irwin Shapiro has used all four of the Viking spacecraft to test the field equations of Einstein's theory of general relativity to a higher accuracy than ever before achieved. Their preliminary analysis of the data so far shows the predictions of this fundamental theory of gravitation to be verified to within an experimental uncertainty of 0.5 percent. Final analysis is expected to yield an uncertainty fivefold lower.

Professor Gordon Pettengill has been using radar to observe Jupiter's four largest moons this past year and has turned up some peculiar scattering properties apparently unique to the outer three of these bodies. When circularly polarized radiation is reflected coherently from a simple surface, its handedness is reversed; radar observations of the moon, Mercury, Venus, and Mars have amply demonstrated this property. If the surface is extremely rough at the observing wavelength, substantial amounts of power can be returned in both rotational senses of polarization. A graduate student, Steven Ostro, found, however, that Europa, Ganymede, and Callisto scattered substantially more energy in the same sense as the incident circular polarization than in the opposite. Furthermore, the reflecting albedos of the satellites are anomalously large. It is believed that multiple scattering from deep craters in the ice may provide an explanation for this peculiar scattering property, and this possibility is now being investigated.

Professors Shapiro and Charles Counselman of the planetary group, along with their colleagues, have combined very long baseline interferometry observations of the moon, lunar-laser ranging data, and a new analytical approach, to obtain the most complete model yet developed of the complex dynamics of the earth-moon system. The predictions of their model agree more closely (within about 25 centimeters rms) with the laser measurements of the earth-moon distance variations than those of any other model. They have used their model to 1) determine the moon's shape and gravity field and the mass of the earth plus moon with unprecedented accuracies; 2) perform the first experimental test of the general relativistic principle of the equivalence of the gravitational and the inertial acceleration of massive bodies; and 3) make very accurate measurements of the variation of the earth's and the moon's vector angular velocities.

Professor John S. Lewis has explored the chemistry of the atmosphere of Jupiter and has found that a number of chemical species in the upper atmosphere may be produced at great depths inside the planet and has shown how observations of the abundances may be used to deduce the rate of vertical mixing of the atmosphere to great depths. In addition, numerical simulations of the growth of the terrestrial planets from large comparable mass protoplanets have been carried out by Professor Lewis and his students.

The research group led by Professor Roger Burns has been working on a variety of geochemical and mineralogical projects centered around the transition elements. Mossbauer measurements have demonstrated that the colors in several blue minerals and gems are caused by the coexistence of and charge transfer between two different iron ions. Scanning electron microscopy

measurements of manganese nodules have led to a better understanding of how nickel and copper become concentrated in nodules from the north equatorial Pacific. Burns and his colleagues have demonstrated that post depositional recrystallization involving biogenic debris, altered volcanic rocks, and oxides of manganese and iron, occurs inside the nodules leading to the formation of a variety of minerals. Nickel and copper are derived from the degradation of organic debris falling to the seafloor.

Personnel

Professor Frank Press resigned his position as Head of the Department to become Science Advisor to the President and Director of the Office of Science and Technology Policy. Professor Wunsch, Cecil and Ida Green Professor of Physical Oceanography, has been named Acting Head, and a search for a permanent Department Head has begun. Dr. Hurley, Professor of Geology, retired on June 30, 1977, after more than 40 years of service in the Department. He will remain, however, as a Senior Lecturer and will continue to teach and do research. Professor Burchfiel from Rice University joined our faculty in January 1977, as Full Professor of Geology. He specializes in regional geology and already is attracting a number of students to his field. Dr. Bally visited us as Crosby Professor during the spring term. He is with Shell Oil Company in Houston, and taught a course in Petroleum Geology as a part of our effort to bring individuals from industry into our graduate program. Dr. John Bennett, who had been an Assistant Professor of Physical Oceanography for three years, has returned to the Great Lakes Environmental Research Laboratory, National Oceanic and Atmospheric Administration, in Ann Arbor, Michigan. Professor Thomas McCord, who has been on leave of absence from his position as Associate Professor of Planetary Science, has accepted a position at the Institute for Astronomy, University of Hawaii at Manoa and has closed down his large research operation at M.I.T. Dr. Burns, Professor of Geochemistry, has completed a sabbatical leave at the Scripps Institute of Oceanography.

CARL WUNSCH

Department of Mathematics

1976-77 was a banner year for honors and awards to the Mathematics faculty. Professors Michael Artin and Louis Howard were elected members of the National Academy of Sciences, and Professor C. C. Lin received the National Academy of Sciences 1976 applied mathematics and numerical analysis award. Professor Gilbert Strang was awarded the 1977 Chauvenet Prize for expository writing at the Annual Meeting of the American Mathematical Society. Professor Dorian Goldfeld was awarded a Sloan Fellowship, and Professors Carl Bender and Norberto Kerzman received M.I.T. Graduate Student Council awards for outstanding and dedicated teaching.

Our students were not to be outdone, as once again the Department team in the intercollegiate Putnam mathematics examination did well, tying for fourth place nationally. All three team members and one individual contestant received honorable mention.

For the first time this year, the Department introduced the use of programmable calculators into the large service courses, with a series of problem sets involving numerical solution of differential equations, evaluation of integrals, and other numerical approximation techniques. Student reaction during the year was mixed, but most seemed to feel at the end of the courses that the experience, while time-consuming, was valuable. We feel it offers an antidote to the

abstractness of mathematics, as well as an introduction to the use of the calculators themselves. We purchased 14 calculators, but by the end of the year most students were using their own or a friend's.

In an effort to improve instruction in the recitations, the Department rented videotaping equipment several times during the spring to film complete recitations. Sections of the tapes were then played back to the teachers (in groups of four or five). It proved a healthy experience for them to see themselves in action and discuss it with the others. Encouraged by the success of these seminars, we have purchased our own videotaping equipment for a more extensive and systematic program next year.

In spite of the tightness of the academic job market in mathematics, applicants for fall, 1976 admission to the graduate program numbered just over 300, as they have for several years. Out of this group, 23 students were admitted and enrolled, 7 with National Science Foundation Fellowships. The number of women applying and being admitted to our program appears to be increasing. Sixteen percent of the applicants were women, as were 5 of the 23 who enrolled.

Twenty-eight Ph.D.s were awarded: two in artificial intelligence, one in fluid dynamics, one in stochastic differential equations, two in probability and statistics, two in combinatorics, one in logic, three in analysis, one in number theory, two in algebra, two in algebraic geometry, three in differential geometry, four in geometry, and four in topology. Eleven S.M.s were also awarded.

FACULTY

Effective July 1, 1977, Professor Willem Malkus will replace Professor Daniel Kleitman as Chairman of the Applied Mathematics Committee. Professor Strang will continue as Chairman of the Pure Mathematics Committee.

In the area of faculty changes, Dr. Leonard Adleman was promoted from Instructor in Applied Mathematics to Assistant Professor of Applied Mathematics. Dr. William DuMouchel will come to M.I.T. from the University of Michigan Statistics Department as Associate Professor of Applied Mathematics, and Dr. Eugene Trubowitz will come from the Courant Institute of Mathematical Sciences at New York University as an Assistant Professor of Mathematics. Professor Bender is leaving to accept an appointment as Professor at Washington University, St. Louis. Professor Michael Proctor is returning to Cambridge University, England, and Professor Paul Wang is moving to Kent State University.

Visiting faculty during the 1976-77 academic year have been: Dr. Daniel Abbiw-Jackson from the University of Ghana; Dr. Glenys Luke from Oxford University, England; Professor George Lusztig from Warwick University, England; and Professor Michael Woodroffe from the University of Michigan, Ann Arbor.

Faculty members on leave during the year were Professors I.M. Singer (spring), Herman Chernoff (spring), James Mark (spring), and Harold Stark (fall).

This year was the Institute's first without the full-time services of Professor William Ted Martin, who retired from the faculty on June 30, 1976. Professor Martin joined the faculty of M.I.T. in 1936 as an Instructor. His career has had four major components: teaching, research, administration, and the development of programs in mathematics education.

Professor Martin was the fourth Head of the Department of Mathematics, succeeding Henry B. Phillips in 1947; during his 21 years in that role, he instituted the C.L.E. Moore Instructorship program and led a period of faculty development which took us from the status of a small

service department with strength in research to our present position as one of the major centers of mathematical research in the country. He was subsequently Chairman of the Faculty, during two of the most turbulent years our campus has experienced, and he played a major role in holding the Institute's faculty together in the face of extreme internal tensions. He went on to become the first Director of the Institute's Division for Study and Research in Education, with which he is still affiliated although no longer as Director.

Professor Martin's contributions to undergraduate education are reflected in such diverse things as his text on differential equations with Eric Reissner, his lecturing talents, which we are continuing to utilize, and his insistence over the years that we could be a great research department and still provide excellent mathematics instruction for every student at M. I. T. He has made contributions over a period of 15 years to elementary and secondary mathematics education in the English-speaking countries of Africa through his work on the development of suitable mathematics textbooks. This is a role which required extreme dedication and tenacity in addition to the intellectual characteristics which we would associate with effective performance in such a capacity.

The broad range of other contributions Professor Martin has made to the mathematics profession include his positions as Vice President and then Treasurer of the American Mathematical Society and his role over the years as consultant to developing departments around the country.

In the face of these many accomplishments, it is important that we not lose sight of his first love, mathematical research. Much of his research on several complex variables was reflected in his book with Salomon Bochner, which was published by Princeton University Press in 1948. The second main stream of his research is found in 10 joint papers with R. H. Cameron on integration in function space. The third stream consisted of his later papers on function theory on complex spaces.

In the mid-fifties, the increased size of the Department and the increased complexity of administration at M. I. T. transformed Professor Martin's role as Department Head into a full-time job. We know what it must have meant to him to have to move away from his first love and devote full time to administration. We are deeply grateful for the sacrifice he made and hope today's Department is a monument which makes him feel it was worth it.

KENNETH HOFFMAN

Department of Meteorology

There was continued modest growth in graduate student enrollment and support for faculty research this year. Two newly appointed assistant professors made curricular changes reflecting their individual interests. Changes were also made in the doctoral examination schedules for meteorology and physical oceanography to allow more time for formal course work. Discussions were begun with representatives from Harvard University and the National Aeronautics and Space Administration (NASA) looking toward the establishment of a joint M. I. T. -Harvard climate research center to allow for an expansion of the climate research activities at the two institutions. The fund drive to establish a Victor P. Starr Memorial Lectureship exceeded expectations, owing largely to the matching contributions of an anonymous M. I. T. alumnus. The first Victor P. Starr Lecture will be given in fall, 1978 on the occasion of the celebration of the Department's 50th anniversary. The Department is the oldest in the United States devoted to professional instruction in meteorology and physical oceanography.

Enrollment

Student enrollment increased from 59 to 62. Of these, four were women, 14 were in physical oceanography and 48 were in meteorology. Seven Ph.D.s and five S.M.s were granted.

FACULTY

Two new faculty members joined the Department. Glenn R. Flierl, Assistant Professor of Physical Oceanography, collaborated with Professor Jule G. Charney in teaching the restructured course, Physics of Large-Scale Atmospheric and Oceanic Circulations; he also taught 19.83, Physical Oceanography. David Randall, Assistant Professor of Meteorology, offered a new course, 19.66 The Planetary Boundary Layer and Cumulus Convection.

Professor Henry M. Stommel was on sabbatical leave at the Institute for Oceanic Research of the University of Kiel. His replacement, Visiting Professor Melvin Stern of the Graduate School of Oceanography of the University of Rhode Island, collaborated with Professor Erik L. Mollo-Christensen in giving the course 19.93 Special Problems in Oceanography. Professor Mollo-Christensen spent a month as a guest of the Institute of Statistical Mechanics of Turbulence of the University of Aix-Marseilles working on internal wave problems. Dr. Hans Richard Grumm of the University of Vienna and the International Institute for Applied Systems Analysis, gave a series of 20 lectures on Dynamical Systems and Turbulence.

A new visiting professorship funded by NASA's Goddard Institute for Space Studies (GISS) was established for an individual who will spend 60 percent of his or her time in the Department and 40 percent at GISS. After a careful search the Department offered the position to Dr. Jagdish Shukla who accepted.

The death of Emeritus Professor Victor P. Starr in March 1976 was a blow to the Department. He was revered for his human as well as for his intellectual qualities. To perpetuate his memory and to honor itself, the Department established a Victor P. Starr Memorial Fund and proceeded to solicit contributions from his friends, colleagues, and former students. With the aid of the generous matching funds of an unknown alumnus, the Fund has reached our optimistic goal of \$20,000. The Lectureship is therefore assured and will commence in fall, 1978 when the Department celebrates its 50th anniversary.

Honors and Awards

Professor Stommel was awarded the Maurice Ewing Medal of the American Geophysical Union for "significant original contributions to understanding ocean processes." The C.-G. Rossby award for the most outstanding graduate thesis in the Department was given to Inez Fung for her doctoral dissertation, "The Organization of Spiral Rainbands in a Hurricane."

A Climate Research Center

Collaboration with the Goddard Institute for Space Studies has enabled members of the Department to engage in climatic research involving the use of the GISS general circulation model and its high-speed computers. Further studies of climate will require still greater collaboration with GISS as well as interdisciplinary collaboration among meteorologists, oceanographers, and applied mathematicians. The composition of the Department and the strong support from related activities in other departments at M.I.T., Harvard University, and the Woods Hole Oceanographic Institution make it particularly well suited to carry on

such studies. To further this type of research, plans are being formulated for the establishment of a joint M. I. T. -Harvard Climate Research Center with support from NASA and perhaps other governmental and private sources.

RESEARCH

The Weather Radar Project directed by Senior Research Associate Pauline M. Austin has been collecting a comprehensive set of digital data for New England storms. These data are being analyzed to provide quantitative descriptions of storm precipitation patterns and to determine their relationship to the larger-scale circulations. One of the radar systems of the Project was used as a shipborne installation to make extensive measurements of cumulus convection in tropical disturbances during the Global Atmospheric Research Program (GARP) Atlantic Tropical Experiment (GATE), an international meteorological experiment conducted during summer, 1974. The data are included in analytical studies of convective precipitation patterns. Of particular interest is the effect of cumulus convection on the vertical transport of heat and momentum. The project is developing numerical cell models to help in interpreting the observed distribution of radar reflectivity in terms of up- and down-draft characteristics.

Professor Robert C. Beardsley, having transferred to the Woods Hole Oceanographic Institution in 1975, continued as a Lecturer to supervise the research of graduate student Charles Flagg who completed his thesis on the structure and variability of ocean currents on the continental shelf and of the shelf/slope front south of New England, based on a field experiment conducted in the winter of 1974.

Professor Charney has been working with Research Associate Edwin Schneider and Assistant Professor Eugenia Kálnay de Rivas on the development of coupled axi-symmetric models of atmospheres and oceans for the study of the factors controlling the position of the Intertropical Convergence Zone over the oceans and the poleward extent of monsoon circulations over land. He also has been collaborating with Professor Shukla in an investigation of the predictability of monsoon circulations and of drought in the semi-arid regions lying between deserts and their adjoining monsoonal regions. Extensive numerical simulations performed in collaboration with scientists at NASA's Goddard Institute for Space Studies have supported his hypothesis that changes of vegetation in the semi-arid regions feed back significantly through changes in albedo and evaporation rate on rainfall in these regions. This coupling with surface conditions, together with similar coupling with sea-surface temperatures in tropical oceans, appears to offer possibilities for seasonal predictions of monsoon circulations and drought. A third investigation has been directed toward the calculation of unstable atmospheric limit cycles as a means of developing simple dynamical models for climate. This work is being carried out in collaboration with Professor Kálnay de Rivas and Research Associate David Straus. In addition Professor Charney supervised the work of graduate student Inez Fung who completed her doctoral dissertation on a theoretical study of spiral rainbands in hurricanes.

Professor Flierl conducted research on the theory of oceanic motions from the mesoscale (order 100 km) to the general circulation scale. He is particularly interested in modeling Gulf Stream Rings. These are intense (several meters per second) vortices which are formed by a looping of the Gulf Stream and which move hundreds of kilometers from the Stream, carrying fresh, cold water with them. Nonlinear analytical models of these vortices are being constructed to account for their non-dispersive properties and for their ability to entrain, transport and detrain water, and thereby to advect heat, salt, and biological properties. The modeling of the Lagrangian dynamics of the Rings and the nonlinear studies are being coordinated with physical, chemical, and biological experimentation at the Woods Hole Oceanographic Institution, the University of Rhode Island, and Texas A&M University,

institutions involved in observational Rossby wave research. Other aspects of Professor Flierl's research have concerned the calculation of the internal Rossby wave modes of a multiply connected ocean basin and the examination of the instabilities and nonlinear interactions of both internal and external Rossby waves.

Professor Kálnay de Rivas worked on improvements of fourth order differencing schemes for the Goddard Institute for Space Studies general circulation model. In cooperation with Research Assistant Stephen Brenner she performed three-dimensional numerical simulations of the circulation of Venus and studied the effect of neglecting the pressure effect on the temperature in a deep anelastic atmosphere. In cooperation with Research Assistant Larry Marx, she developed an energy conserving model in isentropic coordinates and performed long integrations with heating and friction included. Professor Kálnay de Rivas also is studying the time-averaged unsteady solutions of a two-level quasigeostrophic model with asymmetric orography and heating and the corresponding unstable steady-state solutions. She developed a fourth order energy and potential vorticity conserving scheme which will be tested on a shallow-water model, and collaborated with Professor Charney in adapting a zonally symmetric Boussinesq model for Venus to the study of the axi-symmetric ocean circulation.

Professor Edward N. Lorenz has been investigating the influence of moisture in the atmosphere upon the energetics of the general circulation. He has succeeded in defining a quantity called "moist available energy," which is similar to the previously defined "available potential energy" except that moist thermodynamic processes are involved in the definition. He also has been investigating the extent to which weather and climate are predictable. Under his supervision three doctoral theses were completed during the past academic year. David Salstein dealt in his thesis with the influence of moisture on the short-term predictability of weather, John Roads dealt with the influence of heating on the extent of climatological cloudiness, and Alan Robock dealt with the influence of various factors on the climatological temperature.

Professor Mollo-Christensen has been working on nonlinear internal wave processes and has found that the exact solutions for finite amplitude waves found by Gerstner in 1802 can be modified to described billows at the interface between two stratified layers of air. The same solutions can also be modified to described edge waves of finite amplitude in a rotating system. Another internal wave problem worked out is the reflection of waves generated by a tidal flow over a seamount and impinging on a drifting surface layer. The result is that there will be amplification, and the analysis explains some of the Garp Tropical Atlantic Experiment oceanographic observations. Another reflection problem worked out is an adaptation of a solution of Ribner for acoustic waves impinging on a supersonic shear layer to the analysis of internal gravity waves impinging on a shear current. Singular overreflection is found to occur, a result with important consequences for the interpretation of temporal instabilities in comparison with spatially growing disturbances. In addition, he has worked on satellite image interpretation using the facilities of the Air Force Geophysics Research Laboratory. The work is leading to the identification of internal characteristics of ocean currents and the interpretation of surface temperature observations in terms of subsurface flow processes.

Professor Reginald E. Newell's group has continued its study of the relationship between the sea-surface temperatures of the Pacific, Atlantic, and Indian oceans and the free air temperature. While changes in the Pacific sea-surface temperature pattern precede those of the mean temperature of the tropical troposphere by about six months, changes in the Atlantic pattern are unrelated to mean tropospheric temperature. Indian Ocean changes are linked to those in the Pacific. A practical application of the analysis has been the finding that the rate of accumulation of fossil fuel CO_2 in the air is related to Pacific temperature changes several months earlier; a cold equatorial Pacific is followed by a slower build-up of CO_2 , presumably because the colder nutrient-rich water is more favorable to photosynthesis; colder water may also dissolve more CO_2 . Global free air meridional temperature gradients have also been studied and found to be stronger in the early 1960s when there was greater than average rainfall in Africa than in the early 1970s when there was a drought in sub-Saharan Africa.

Professor Ronald G. Prinn and Research Associates Dr. Derek M. Cunnold and Dr. Fred N. Alyea have continued work with their three-dimensional dynamical-chemical model of the upper atmosphere. An expanded version of this quasi-geostrophic model with increased horizontal resolution and containing some 40 chemical reactions is nearing completion. This version will utilize the ILIAC IV computer at NASA's Ames Research Center. Drs. Alyea and Cunnold are also involved in both satellite and aircraft observational programs with the aim of improving the usefulness of such measurements for model validation. Visiting the project this year were Research Associates Dr. John Barnett of Oxford University who has been successfully comparing model runs with observed satellite radiances and Professor Guido Visconti who has been working on improvements to the treatment of radiative transfer in the three-dimensional model and on the chemistry in a related two-dimensional model.

Dr. Tsing-Chang Chen has recently joined the group to aid in numerical work related to the ILIAC IV model with particular emphasis on computing energy transformations. Accomplishments of the group have included the first complete explanation for the observed ozone distribution between 10 and one millibars, the definition of the scales and phase relationships involved in eddy transport of ozone, the effect of latitude and altitude of aircraft flight on resultant ozone depletion, and finally, the possible role of deserts as sinks for fluorocarbons.

In work on planetary atmospheres Professor Prinn has shown that the recently observed carbon monoxide on Jupiter can be used to deduce the vertical mixing rate in the deep atmosphere. In collaboration with Dr. Robert Huguenin he has also demonstrated the role of the Martian surface in stabilizing the carbon dioxide atmosphere of Mars. In work on radiative transfer he has demonstrated the important roles played by both atmospheric inhomogeneities and surface properties in the damping of temperature perturbations. In particular, radiative damping rates are much greater over oceans than over land surfaces.

Professor Randall calculated apparent heat sources, apparent moisture sinks, and apparent moist potential vorticity sources from data gathered during Phase II of the GARP Atlantic Tropical Experiment. He proposed a convection model for use in interpreting the results of these calculations and developed a model which is being used to simulate processes which destroy layer clouds. He also developed a theory of turbulent entrainment into a cloud-topped planetary boundary layer (PBL). Professor Randall performed numerical simulations of the cloud-topped PBL, of radiative-convective equilibrium over a tropical ocean and the diurnal cycles of convection over land, and performed simulations of the global circulation of the atmosphere in collaboration with Professor Akio Arakawa and collaborators at the University of California at Los Angeles.

Professor Frederick Sanders and his students studied major thunderstorm systems of the central United States and obtained a self-consistent picture of the transports of heat, moisture, and momentum by the cumulus clouds within the mesoscale circulations of these systems. A doctoral dissertation in progress is aimed at simulating the major features of this type of system in a dynamical model. In a study of oceanic storms of middle and high latitudes it was found from a dynamical model that air-mass contrasts are insufficient to account for their occasional great intensity, indicating that organized cumulus convection may play an important role in these as well as in tropical storms.

Professor Stommel is preparing for a study in 1978 of the equatorial current system in the western Pacific near the Gilbert Islands as a sequel to the past two years' investigation of equatorial currents in the Indian Ocean near the Seychelles. Both these regions are subject to monsoonal winds, and hence are favorable for studying the response of the ocean to variable forcing. A more complex type of variability is the mesoscale eddy--occurring widely over the oceans--being studied in the region south of Bermuda in a joint US/USSR investigation during 1977-78 bearing the name POLYMODE. Professor Stommel is cochairman with Professor Allan R. Robinson of Harvard of the US POLYMODE Organizing Committee and is responsible for the M. I. T. Executive Office which coordinates the US part of the POLYMODE program for a number of cooperating US universities.

Department of Nutrition and Food Science

During a sabbatical at the Institut für Meereskunde, Kiel, West Germany, Professor Stommel and Dr. Friedrich Schott discovered the "beta-spiral," a phenomenon in the mean current field of the main thermocline in all the subtropical gyres of the world ocean which gives a strong indication of the nature of the vorticity balance and puts upper limits on the amount of vertical mixing in mid-ocean. The existence of the "beta-spiral" permits the solution of a century-old problem in oceanography: the local determination of the absolute mean velocity field from density data alone. Limitations of applicability of the method are being explored using data from all oceans.

Professor Peter H. Stone collaborated with the Goddard Institute for Space Studies on 1) diagnostic calculations of atmospheric eddy heat fluxes, 2) the development of simplified general circulation models, and 3) studies of the sensitivity of the Walker circulation to sea-surface temperature. He analyzed the sensitivity of the dynamical flux of heat from equator to pole in the atmosphere-ocean system to external and internal parameters. Professor Stone directed student research on 1) seasonal changes on Mars, 2) the sensitivity of transient eddy heat fluxes to the vertical structure of the atmosphere, 3) the development of simple heat balance climate models, 4) the eddy heat fluxes associated with stationary atmospheric eddies, and 5) the influence of soil hydrology on atmospheric conditions.

JULE G. CHARNEY

Department of Nutrition and Food Science

During the past year the research and educational activities of the Department have shown continued growth as measured by numbers of postdoctoral associates, graduate students, and undergraduates, whereas the number of faculty has remained unchanged. More than 400 research and review papers were published or accepted for publication during the past year, and the faculty has continued to be active in various national and international advisory bodies.

Undergraduate Education

Enrollment in the undergraduate curriculum in Applied Biology, Course VII-B, is remaining constant. In spring, 1977 the enrollment was 112, distributed as 42 seniors, 52 juniors, and 18 sophomores. Since the establishment of the program in 1971, 121 students have graduated as of June 1977. The faculty has continued to be active in the Undergraduate Research Opportunities Program (UROP) and in other modes of interactions with undergraduates as shown in the following table.

Undergraduate Student-Faculty Interactions Outside of Course Work

Year	Number of UROP Students		Number of Undergraduate Seminars	Number of Freshman Advisors	Pre-Med Students Advised	VII-B Students Advised
	Fall	Spring				
1970-71	7	14	--	--	--	--
1971-72	34	56	2	12	65	11
1972-73	60	86	8	9	39	25
1973-74	103	102	6	6	42	55
1974-75	103	118	11	10	45	94
1975-76	102	112	9	12	49	116
1976-77	86	97	6	16	56	112

This summer, 50-plus undergraduates are doing research full time. They are being supported as follows:

UROP & faculty funds.	33
National Science Foundation/ Undergraduate Research Participation Grant (NSF/URP	12
Other (credit, nothing, faculty funds)	<u>5+</u>
TOTAL	50+

Summer research opportunities are further increased by funding of an NSF/URP grant for 12 students; Professor Charles Cooney is the project director and has been awarded the grant for a three-year period.

Summer and the January Independent Activities Period both continue to be opportune times for undergraduates to do full-time research without the competition of course work.

Graduate Education

The enrollment of 181 regular graduate students as degree candidates beginning in September 1976 was an increase of 22 from the previous September total. During the year, 27 students received their S.M. from the Department and 15 the Ph.D. Approximately 15 more are expected to complete degree requirements during the summer. Applications to all of the programs greatly exceed the resources to support graduate students and the space available.

Foreign students constitute 35 percent of the total student body, unchanged from last year. Two students are from Canada, 11 from Europe, 18 from Central and South America, six from the Middle East, 24 from Asia, and five from Africa. Women constitute approximately one-third of the graduate students in the Department with an increase of nine this year distributed among the programs in Food Science and Technology, Nutritional Biochemistry and Metabolism, and Neural Endocrine Regulation.

Recruitment of minority students is being pursued actively, and a brochure has been prepared for distribution to potential minority applicants and to minority schools with curricula which prepare their graduates for graduate programs such as ours.

Conferences and Summer Courses

The fourteenth Annual Underwood Prescott Memorial Symposium was held on September 28, 1976, in honor of Dr. Betty C. Hobbs. Dr. Hobbs, Dorothy F. Hollingsworth, Order of the British Empire, and Professor Rose Marie Pangborn presented the symposium on "Better Food: The Science of Nutrition, Safety, and Flavor."

Five one-week summer courses were given in 1976 and were attended by industry, government, and university scientists. A listing of subjects and their attendance follows.

Enzymes and Their Uses in Analysis and Clinical Diagnosis

Director: Professor George Wolf
July 12 through July 16, Attendance: 31

Advances in Food Science and Technology

Director: Professor Marcus Karel
July 19 through July 23
Attendance: 38

Advances in Human Nutrition Knowledge

Director: Professor Vernon R. Young
July 26 through July 30
Attendance: 47

Fermentation Technology

Director: Professor Daniel I. C. Wang
August 9 through August 13
Attendance: 46

Concepts and Techniques in Experimental Pathology and Toxicology of Natural and Man-made Agents

Director: Professor Paul M. Newberne
August 16 through August 20
Attendance: 36

This summer (1977) four courses will be given:

International Nutrition: Problems, Policies, and Strategies

Director: Professor Max Milner
July 18 through July 22

Advances in Food Science and Technology

Director: Professor Karel
July 25 through July 29

Advances in Human Nutrition Knowledge

Director: Professor Young
July 25 through July 29

Fermentation Technology

Director: Professor Wang
August 8 through August 12

International Nutrition Planning Program (I.N.P.)

The I.N.P. Program was established by the Department in 1973 in cooperation with the Center for International Studies and the Departments of Economics and Political Science. The Department of Urban Studies is now also participating. During the year 18 students were enrolled in the program--10 from Nutrition and Food Science, one from Urban Studies, five from Political Science (including two special students), and two from Economics. There were four advanced study fellows--two from Morocco, one from Colombia, and one from France. Staff and students in the program were involved in field research in Guatemala, Brazil, Egypt, Pakistan, Malaysia, the Philippines, India, and Papua New Guinea.

Clinical Research Center

During the past year, 27 active projects have been carried on at the M.I.T. Clinical Research Center (C.R.C.); 147 admissions were made, and 3,784 patient days of care were rendered. The studies under the direction of Professors Young and Nevin S. Scrimshaw and their post-doctoral fellows and graduate students were devoted to such matters as amino acid and protein, as well as energy requirements of humans, and the nutrition of children with thermal burns in collaboration with the Shriners Burns Institute of the Massachusetts General Hospital. Professor Robert M. Suskind and his group have been studying in both the C.R.C. and the Children's Hospital, patients with cystic fibrosis and their nutrition requirements, problems of obesity in adolescents, and nutritional support of children with cancer.

The Department of Psychology has continued to make important contributions to and to use the Center, particularly under the direction of the late Professor Hans-Lukas Teuber in collaboration with Drs. Thomas Twitchell and Suzanne Corkin.

Professor Richard Wurtman and his colleagues have been studying neurological diseases, particularly Huntington's Disease and its relation to diet.

Drs. Robley Evans and Melvin Chalfen of the Argonne National Laboratory, Center for Human Radiobiology in Phoenix, Arizona, and here at M.I.T. have continued their studies of bone-seeking radioisotopes in humans.

Professor Ronald Arky (Harvard Medical School) has continued his studies of obesity and the effects of starvation and refeeding.

Dr. George L. Blackburn and his colleagues have added to their data on obesity and, in collaboration with Professor Suskind, on the effect of malnutrition on immunity.

FACULTY

Promotions within the Department included Drs. Young to Professor of Nutritional Biochemistry, Anthony J. Sinskey to Professor of Applied Microbiology, John D. Fernstrom to Associate Professor of Physiology, and William G. Thilly to Associate Professor of Toxicology. New appointments are Drs. Thomas D. Lockwood, Assistant Professor of Toxicology, and Noel W. Solomons, Assistant Professor of Clinical Nutrition. Other changes included the resignation of Drs. Loy C. Lytle and Maria C. Linder and the change of appointment of Dr. Charles S. Davidson to Senior Lecturer.

Honors and Awards

Dr. Michael C. Archer, Associate Professor of Biological and Food Chemistry, received a National Institutes of Health Research Career Development Award. Dr. Charles L. Cooney, Associate Professor of Biochemical Engineering, was awarded the Becten-Dickinson Award by the American Society for Microbiology. Dr. Samuel A. Goldblith, Underwood-Prescott Professor of Food Science, received the Outstanding Food Scientist Award from the Philadelphia Section of the Institute of Food Technologists. The Franklin Institute gave Institute Professor Scrimshaw the first Bolton L. Corson Medal for a significant contribution to the field of human nutrition. Dr. Gerald N. Wogan, Professor of Toxicology, was elected to the National Academy of Sciences, and the American Institute of Nutrition gave Dr. Wolf, Professor of Physiological Chemistry, the Osborne-Mendel Award for excellence in basic research in nutrition.

NEVIN S. SCRIMSHAW
MARCUS KAREL

Department of Physics

This was another good year for the Department. The most notable single event was, of course, the award of the Nobel Prize for Physics to Professor Samuel C. C. Ting, for his discovery of the J/ψ particle. Professor Burton Richter of Stanford University, who shared the prize with Professor Ting, is himself an M.I.T. graduate (Class of 1952) and obtained his Ph.D. in Physics in 1956 under the supervision of Professor L. S. Osborne. On April 6, 1977, a full-day seminar was held on the theme "At the Frontiers of Particle Physics;" it began with a film of the Nobel Prize ceremonies, and continued with a number of talks in which Professor Ting and colleagues from the Department, as well as from outside the Institute, summarized the exciting new physics.

The size of the Department remained essentially constant, with a total of 86 faculty, 248 graduate students and 292 undergraduate physics majors. Degrees awarded during the year numbered 38 Ph. D. s, 15 S. M. s, and 84 S. B. s.

The research of the Department continued to be very active, including such diverse topics as observational and theoretical work on neutron stars and galactic x-ray sources, experimental and theoretical studies of critical phenomena, refined tests of general relativity, and nuclear and elementary particle research at all energies, with a special emphasis on the quark model of nucleons. These and many other topics are described in more detail in the divisional reports that follow.

A gratifying feature of the Department's activities was the flourishing state of the Student Physics Society, as expressed in the Student Newsletter, the Undergraduate Colloquia, the extensive use of the Undergraduate Physics Common Room, and student interest and involvement in the work of the Department's committee on undergraduate education.

ASTROPHYSICS

The M. I. T. x-ray observatory on the Third Small Astronomy Satellite, SAS-3 continued to function well during the past year. On May 7 it began its third year in orbit. The observatory is controlled from the Goddard Space Flight Center in accordance with directions sent from the operations room in the Center for Space Research (C. S. R.) at M. I. T. X-ray astronomers at C. S. R. use the observatory in a highly interactive way, adjusting observing tactics on short notice in response to unexpected developments and discoveries. Among the most interesting results from the SAS-3 observations during the past year are the discovery of more than a dozen sources of repetitive X-ray bursts, the discovery of powerful X-ray emission from the Seyfert galaxy 3C120, and the determination of the dynamical properties of pulsating binary X-ray sources through the measurement of the Doppler variations of their pulse frequencies. The latter investigations have led to significant refinements in the determination of the masses of the neutron stars whose accretional processes are the source of X rays in these binary systems.

Two M. I. T. experiments are scheduled to fly on the X-ray satellite HEAO-A, to be launched later this year. A rotating modulation collimator, developed jointly with the Smithsonian Astrophysical Observatory, will measure X-ray source positions accurately, and determine their angular structure, while a high energy experiment, conducted jointly with the University of California at San Diego, will measure X-ray spectra in the energy range 15 Kev to 10 Mev.

Utilizing all four of the Viking spacecraft, our radio-physics group has tested the field equations of Einstein's theory of general relativity to higher accuracy than ever before achieved. Preliminary analysis of the data so far obtained shows the predictions of this fundamental theory of gravitation to be verified to within an experimental uncertainty of 0.5 percent. The final analysis is expected to yield an uncertainty fivefold lower.

Radio astronomy research has included work on the physics of the interstellar medium, and the continuum radio properties of galaxies. Dark interstellar clouds, dark globules, infrared sources, and molecular clouds have been studied in transitions of formaldehyde, carbon monoxide, carbon monosulfide, methanol, ammonia, hydroxyl, hydrogen, and water, using telescopes at Haystack Observatory, the National Radio Astronomy Observatory, and Arecibo Observatory in Puerto Rico. These studies yield information on the chemical, physical, and evolutionary properties of such systems.

Several examples of 21-cm atomic hydrogen absorption in radio galaxies have been discovered including the Seyfert galaxies Markarian 1 and Markarian 6, and the radio galaxy 3C178. The absorption appears to be caused by gas at some distance from the galactic plane, either ejecta from the active nucleus of each galaxy, or else from gas in the "intra-cluster medium."

Infrared and optical studies are now active areas of research in the astrophysics program. During the past year M. I. T.'s time allotment at the McGraw-Hill observatory was fully used in the study of optical stars associated with X-ray sources. A computer data acquisition and processing system has been installed and interfaced to three of the prime focal-plane instruments. Optical observations of X-ray stars and searches for optical counterparts have been carried out in several runs at Cerro Tololo Interamerican Observatory (4m, 1.5m, and 1m telescope). Observations include photographic, photometric, and spectroscopic searches for optical counterparts of X-ray sources, X-ray/optical observations of burst sources and pulsars, and studies of an X-ray globular cluster. We also observed evidence of an episode of optical pulsations from a slow X-ray pulsator (X-Persei).

A major program to test the results of the Air Force Mid-infrared Sky Survey was completed during the past year. A majority of the new sources in the Air Force Cambridge Research Laboratory catalogue were shown to be spurious. The confirmed sources were studied comprehensively, using the facilities of the Kitt Peak National Observatory, the Kuiper Airborne Observatory of NASA, and the Haystack Radio Observatory.

A program of high resolution spectroscopy at 2 microns was carried out for red and reddened stars. Acetylene was identified as a strong feature in carbon stars, representing the first time this compound has been seen outside the solar system. In the near infrared continuum, a peculiarly compact globular cluster associated with the rapid burst X-ray source M x B 1730-335 was found.

Measurements of the large-scale anisotropies of the primeval cosmic background radiation in the spectral region embracing the black body peak of a 3° K source have continued this year. The radiation is isotropic to 0.1 percent on angular scales of 17 degrees and larger. The limits set on a global dipole anisotropy indicate that the velocity of the earth relative to the most distant universe is less than 350 km/sec. Galactic dust emission is a major "noise" source in the data.

The galactic plane has been mapped in the mm and submillimeter region with 1.5 degree angular resolution. The emission by interstellar dust clouds follows roughly the molecular carbon monoxide maps. The spectral index of the dust varies as the frequency to 3.5 power or faster.

Work has begun on the COBE satellite which is intended to make the definitive measurement of the spectrum and large-scale angular anisotropy of the cosmic background radiation as well as set limits on the diffuse infrared background between 300 and 8 microns. The satellite is scheduled for launch in 1983.

Interplanetary plasma studies have produced a number of new results. In studies of solar-wind/planetary interactions, 1) subsolar magnetosheath observations in the subsonic region have shown clear effects due to dayside merging; 2) observations near Mercury indicated an Earth-like magnetosphere but scaled down because of Mercury's weaker magnetic moment; a substorm was probably seen at the first encounter; and 3) an unknown feature on Jupiter associated with non-Io-related decametric emissions has been identified as being related to Jupiter's injection of interplanetary electrons.

In interplanetary studies we found that conflicting results on the nature of directional discontinuities can be explained by the observation that the importance of rotational, relative to tangential, discontinuities increases in higher speed wind. We found a correlation between 1 and 7 AU observations which indicate that the trailing edges of high-speed streams often have a spatially well-defined coronal source. In a joint effort with American Science & Engineering, it was found that all large equatorial coronal holes are associated with high-speed streams but the reverse is not true. In a joint effort with the University of California at San Diego, good agreement was found between solar wind speeds determined by spacecraft and the radio scintillation technique, an encouraging result that can lead to out-of-the-ecliptic information.

A wide range of problems in theoretical astrophysics was studied over the past year. An area of particular interest has been the study of neutron stars which apply and test the laws of physics in conditions of high temperature, density, and gravitational field. The suggestion that "neutron" stars are in fact composed of quarks ("quark bag" stars) appears to be testable by future observations of redshifted X-ray or gamma-ray lines (produced by positron annihilation or cosmic ray spallation) which arise from the "neutron" star surfaces, and may also provide a test of the strong principle of equivalence for intense gravitational fields.

The limits to neutron star masses have been examined, and it appears that the pressure can be increased above the energy density, leading to more massive neutron stars allowed by general relativity (perhaps as high as 8 M_{\odot}) and to an infinite upper mass limit in the Bimetric Theory of Rosen. Constraints on neutron-star masses have been derived from observations of neutron stars in close binary stellar systems; and model calculations have been made for thermonuclear flashes that occur in the surface layers of accreting neutron

stars. There is increasing observational evidence that the distribution of elements is not uniform, and the effects of initial chemical inhomogeneities within stars upon subsequent stellar evolution are being investigated.

The supernova explosion process has continued to be examined, and the newest work accounts quantitatively for the light curve, frequency shifts, and relative intensities of all spectral lines of significance in Type I Supernovae. The new idea is a strong excitation of the expanding cooled gas shell due to the fluorescent decay of distant gas. The SN contains an inverted planetary nebula, in a way. The same model leads to a proposal for certain gamma-ray point sources, derived from SN cosmic ray emission.

ATOMIC, PLASMA, AND SOLID - STATE PHYSICS

According to a fundamental theorem postulated 40 years ago by Landau and Peierls, a solid state is only possible for systems in which the density depends on three or more coordinates. In other words, one- or two-dimensional solids cannot exist. The establishment of a one-dimensional density wave in a three-dimensional liquid presents a situation closely related to the two-dimensional solid; in each case density fluctuations are predicted to diverge logarithmically with the sample size, thus destroying the possibility of the long-range order required for a solid phase.

The first experimental verification of these ideas has now been achieved using a one-dimensional density wave system provided by nature; a smectic liquid crystal. Studies of a smectic liquid crystal by high resolution X-ray scattering show that the normal Bragg peak in the scattering cross section is absent. Instead, a power law singularity, related to the logarithmically diverging fluctuations, is observed. The experiments, which clearly confirm the lack of long-range order as predicted long ago by Landau and Peierls, are expected to stimulate modern theoretical calculations.

The study of critical phenomena has recently been extended to polymers by the application of light-scattering spectroscopy to gels. (A gel is an infinite crosslinked polymer network immersed in a fluid.) Concentration fluctuations of the polymer network of a polyacrylamide gel have been observed. As the temperature is lowered and approaches -15°C the fluctuations show the divergence and slowing down characteristic of a critical point: the scattered light intensity diverges and the correlation time of fluctuations of scattered light intensity becomes much longer. The behavior has been explained as critical phenomena arising from the phase separation of the binary mixture of the polymer network and the fluid medium. Essentially, the transition results in a shrinkage of the polymer network. The dynamics and statics of the phase separation have been qualitatively described by theories analogous to mean field theory and mode-coupling theory. These findings provide important knowledge and a powerful technique for the study of polymers.

An immediate application of the study of gels is to our understanding of the physiology of retinal detachment which occurs as a result of the shrinkage of the vitreous gel. An *in vivo* method to observe the protein diffusivity in the intact lens using laser light-scattering spectroscopy with smaller light power than an ophthalmoscope has been developed in collaboration with Dr. Leo Chylack of the Harvard Medical School. A clinical instrument which will be installed in Massachusetts Eye and Ear Infirmary is being designed. The goal is to detect cataract formation at a very early stage and to monitor development and retreat of a cataract during clinical treatment.

First results have been obtained with a new technique for the study of a system composed of a small number of particles with short-range interactions resembling an atomic nucleus. The "nucleus" in this experiment is a droplet of liquid helium between one and 100 atoms in size. The droplets, formed by condensation in a supersonic beam of helium gas, are

ionized and detected in a mass spectrometer. Measurements of the spectrum of droplets so produced reveal that certain sizes are particularly abundant relative to their neighbors. These "magic numbers" probably reflect increased binding due to some aspect of the droplet structure. Current work centers on study of the influence of source and detector conditions on the droplet spectrum. Plans include the study of droplets of the isotope ^3He , and more elaborate experiments to measure the spins and vibrational frequencies of helium droplets.

A new apparatus for the study of plasmas has been brought into operation. Versator II is a research tokamak which provides an unusual amount of experimental access to the plasma. The device, the most flexible of its kind, will be used initially to test different radio frequency heating mechanisms for tokamak experiments. In the first series of experiments, 50 kilowatts of microwave power at 800 megahertz will be injected into a plasma at the lower hybrid frequency. In the second series of experiments 200 kilowatts of power at a frequency of 36 gigahertz will be injected at the electron cyclotron frequency.

The study of weakly bound diatomic molecules has been advanced by a combination of molecular beam and tunable laser techniques. The system, an alkali-rare gas molecule, is of interest because it is simple enough that it has been the focus of several theoretical investigations. The molecules are created by free expansion of a high pressure gas into a vacuum, which results in dramatic cooling of the gas. Temperatures on the order of one degree Kelvin have been observed in an expansion of Ne gas seeded with Na, low enough to result in the formation of weakly bound NaNe molecules. (The ground state of NaNe is by almost an order of magnitude the most weakly bound diatomic molecule ever studied in a molecular beam.) The molecular spectrum of these molecules has been studied using a high resolution tunable dye laser and is being interpreted to yield highly accurate interatomic potentials for NaNe.

The NaNe potential curves are relevant to problems of stellar atmospheres and to a variety of elastic and inelastic scattering processes. The major significance of the work, however, is that it provides reliable potentials to serve as input for theories for these processes, providing the first opportunity to check the theories in a clear-cut fashion.

CENTER FOR THEORETICAL PHYSICS

Elementary Particle Theory

The particle theory group is concerned with the structure of hadrons, the fundamental interactions between hadrons, and the weak and electromagnetic interactions.

About five years ago, after the parton-model analysis of the M. I. T.-Stanford Linear Accelerator Center deep inelastic scattering experiment, many people became convinced that we had to take the picture of hadrons as being composed of elementary point-like quarks as a literal truth. Furthermore, it was necessary that the quarks be permanently confined. After a number of false starts, the M. I. T. bag model was developed, starting about three years ago. It has proved to be a very useful model which unifies in a simple way many diverse aspects of strong interaction phenomenology. We are continuing to work on the model, in order to see if it can be developed into a theory for hadron structure. Some of the developments are:

The energies of the lowest excited states of three quarks confined within a bag were evaluated using a previously developed Hamiltonian method, that allows for a proper treatment of center of mass motion and boundary deformations.

A study of deformation energies of hadrons within the framework of the static bag model of quarks and gluons is being completed. In particular we are calculating the effective potential

between two nucleons as a function of the overall quadrupole moment of the six-quark system. Preliminary qualitative results reproduce the repulsive core and intermediate range attraction in the deuteron channel. This work is the first attempt at calculating the inter-nuclear potential in the context of a quark-gluon theory.

Computations have been made of electromagnetic properties of charmonium, including decay widths, electromagnetic mass differences and photoproduction cross sections. Comparison of the non-relativistic quark model with the more sophisticated "bag" model is being undertaken. It is intended to extend the calculations to higher energies, and to include the possibilities of heavier quarks with new attributes.

We are engaged in a study of the phenomenological aspects of quark confinement. Most recently we have been studying baryons composed of more than three quarks and mesons composed of more than a single quark-antiquark pair. We have found that one meson multiplet previously classified as a single pair in a relative P state is actually much better described as consisting of two pairs.

In the past year we have been working on the relativistic many-body theory of quark matter. We developed techniques which enabled us to calculate the ground state energy of a quark gas in an approximation valid to fourth order in the strength of the quark-gluon interaction. We have applied the results of our calculations to the description of dense matter occurring in heavy pulsars.

Partly as a result of the above developments, much of our research interest has turned to understanding how quarks can be confined in a relativistic quantum theory. There are at least two approaches to this problem. The most fashionable is to start with a conventional gauge-field theory, like Quantum Chromo-dynamics, and demonstrate confinement. Another approach is to start with a string theory, which has ab initio a confining potential, and then in the context of such a theory to calculate the properties of a hadron in order to confront the theory with experiment. It is possible that both approaches represent different starting points to the same theory. We have begun a serious program to understand the physical consequences of string theory. We have developed a lattice approach to interacting string theory which promises to enable us to understand non-perturbative effects.

On the other hand we are continuing a vigorous line of research on the properties of Quantum Chromo-dynamics. We have found several new solutions to Yang-Mills theories and we are extending our semiclassical analysis of quantum field theory, with the hope of understanding the physical content of these nonlinear quantal structures. The program is to solve the field equations as classical c-number equations and to establish the significance of the solutions for the corresponding quantum field theory. The program has been most successful; we have shown that there exist unexpected particle states with new quantum numbers. Specifically we have found that particles with half-integer spin can be built from Bose fields and have shown that the vacuum state of a Yang-Mills theory is degenerate. The results also have physical consequences, in that the degeneracy of the vacuum removes an unwanted symmetry in popular quark models and gives rise to a CP violating phase angle. Further research in this area is contemplated.

Nuclear Theory

The nuclear theory group works on the full range of problems associated with modern nuclear physics.

We have a continuing interest in collective models of the nucleus including nuclear rotational motion, vibrations, and the coupling of single particle motion to these modes. In particular, work has been completed on a double variation method for describing rotational motion,

which puts the "cranking model" into a more fully quantum mechanical context. Applications are in progress. Further work on the relevance of the time-dependent Hartree-Fock approximation in rotations is also under way.

The recently discovered Multipole Giant Resonances are a current field of interest. Both the decay widths and the spreading widths of the giant resonances can be described by an extension of the conventional RPA to include the continuum and a coupling of the single-particle excitations to low-lying collective states. As one result of this work, a strongly collective M_1 state is found at 25 MeV in ^{208}Pb , which might be detected by inelastic electron scattering. We have given a derivation of the effective particle-hole interaction as the second functional derivative of the ground state energy with respect to the density. This approach, patterned after Landau-Migdal theory, provides a unified model of both the ground and the collective excited states and automatically satisfies the sum rules, and we hope to exploit this further.

The work on large-amplitude collective motion in the adiabatic time-dependent Hartree-Fock (ATDHF) limit has continued. Collective motion is parametrized, and the equivalence of the collective dynamics to two formally time-independent self consistency conditions established. One of these conditions represents a constrained variational equation for the ground-state wave function. The work has been generalized to include a certain number of small amplitude, RPA vibrational modes superimposed on the large-amplitude adiabatic collective mode. The main result is the exact form of the coupling between these two types of motion. These methods should lend themselves to the description of collective modes in finite temperature systems, that is, in the non-equilibrium statistical mechanics of hydrodynamic flow and transport processes. Conventional methods of incorporating space-time varying temperature and chemical potentials as collective variables are not very satisfactory. This seeming detour may give us some clues to the question of formulating a consistent nuclear "hydrodynamics."

There is also a long-time continuing interest in the statistical theory of nuclear reactions including compound nucleus processes, quasi-equilibrium processes, direct reactions through coupled channel, and statistical methods. A statistical theory of multistep direct reactions at relatively low energy has been completed. Some practical applications have been suggested and we hope to verify some of the assumptions by a direct test of experimental polarization cross sections. Some of the methods found useful here ought to be applicable to the theory of strongly damped collisions. Work is continuing on the role of the final "compound" nucleus in direct reactions to highly excited final states in the continuum.

The theory of heavy ion reactions has been pursued through the method of generator coordinates as well as through time-dependent variational approximations. In this connection, we have been particularly interested in understanding dissipative processes in a proper quantum mechanical framework. As part of this program, numerical solutions of the time-dependent self consistent field approximation were first started at M.I.T. several years ago. This has started a worldwide explosion of activity in the field. In collaboration with other groups, time-dependent calculations of various heavy ion reactions, as well as nuclear fission, have been performed.

The group has also maintained a strong activity in the area of intermediate-energy nuclear physics including electron scattering from nuclei, high-energy proton multiple scattering problems, and meson nucleus interactions at various levels of sophistication. In addition, work is continuing on the nuclear aspects of the K-meson/nucleus interaction. In particular a new discussion of the strangeness symmetry potential is under development.

In connection with the experimental work at the M.I.T. Bates electron linac a significant effort is going into understanding exchange current effects as well as calculating various interesting elastic and inelastic form factors to compare with the data.

More recently, several of us have formed a strong interest and commitment to theoretical problems associated with the new field of relativistic heavy ion interactions.

We have formulated a theory of fragmentation of relativistic projectiles. The principal experimental results are understood, including independence of target nucleus of branching ratios, cross section dependence on radius of target nucleus, "spherical" angular distribution, energy independence of the cross section, the low average kinetic energy in the projectile frame, and the relatively higher fraction of fast protons observed.

We have also begun work on the possible formation of quark matter in relativistic heavy ion collisions. It appears possible to produce this new form of matter with present accelerators.

Astrophysical Plasma Theory

The long-range nature of the gravitational force and the physical properties of the distribution of stars in a galaxy indicate that many problems of galactic dynamics can be described in terms of collisionless plasmas. A major problem, the formation and maintenance of a spiral structure in flat galaxies, has been successfully formulated by the well-known Density Wave Theory. In particular, studies have been made of phenomena which have counterparts in the physics of electromagnetic plasmas such as the properties of trapped star orbits, which corotate with the spiral field, in the presence of nonlinear collective scattering processes. This work, and the analysis of growing global spiral modes in current galaxy models, has provided the opportunity for a close and fruitful collaboration with Professor C. C. Lin and his associates in Applied Mathematics at M. I. T.

Work has also been carried out in collaboration with Harvard on problems of solar physics concerning, in particular, the heating of the solar corona and the onset of flares.

Condensed Matter Theory

The focus of work in this area has been the theory of critical phenomena. As a model which is solvable and not mean field, the critical exponents of the Bethe (1935) superlattice have been computed for order-disorder transitions in β -Brass. The nonlinear N-vortex problem in 2 space and 1 time dimension has been solved for its critical properties in order to understand the x-y, or planar, spin model. Work is proceeding on a formulation of (1/f)-noise theory; and also the Schwinger source theory formalism, at criticality, to obtain relevant critical exponents at phase transitions in a non-perturbative way.

Research has also been conducted on the following topics: 1) nonlinear crossover and analyses of Xe coexisting density data near the critical temperature; 2) differential renormalization group formulation of critical dynamics; 3) critical equations of state, onset of helical order, and wave-vector dependent correlation functions; and 4) tricritical behavior of He^3 - He^4 mixtures in $2+\epsilon$ dimensions.

EXPERIMENTAL NUCLEAR & PARTICLE PHYSICS*

During academic year 1976-77, the Department's Division of Nuclear and High-Energy Physics continued to pursue a program of researches in these fields that is as basic, broad, deep, and varied as that of any other department, anywhere. Nuclear structure studies have leaned heavily on projectiles of both heavy ions and electrons on a great variety of nuclei,

*For a more extensive discussion, see the report of the Laboratory for Nuclear Science, under whose aegis much of the research of this division is carried out.

thereby probing the nucleus through both the strong and the electromagnetic interactions. In the case of the former, using alternately the Tandem van de Graaff generator at Brookhaven and the Super Heavy Ion Linear Accelerator (HILAC) at Berkeley, the heavy ion group continues to carry out its pioneering studies on heavy ion fusion, on the formation of nuclear quasi-molecular states and on the fundamentals of the fission process and formation of fission isomers. The use of the electromagnetic probe, at the Bates Linear Accelerator, has led to a generalization of the old method of using X-ray and electron diffraction for studying structure into entirely new directions, permitting the investigation of the charge and magnetization distributions in a variety of excited states of complex nuclei, elucidating the nature of the nuclear binding and the internal currents of the mesons that are believed to serve as the nuclear glue.

The elementary-particle physics counter/spark-chamber group has continued to analyze the strong production of a variety of hadrons by a variety of projectiles at the Fermi National Accelerator Laboratory, using a precision hadron spectrometer of their own design. This spectrometer is now being turned to the study of the cascade production of hadrons in heavy nuclei, a study which is revealing a number of illuminating surprises in the nature of the interaction mechanisms.

The accelerator physics collaboration was busy exploiting a unique new instrument, a hybrid bubble-chamber/counter system, which is turning out to have a remarkable capability of analyzing in detail (product particle by product particle) approximately 80 percent of all the complex interactions that occur when protons are bombarded by the variety of projectiles available at the Fermi lab at energies up to 400-500 billion electron volts.

Finally, the electromagnetic interaction group, fresh from the triumph of its discovery of the J/ψ particle, is extending its techniques to look for new particles and new interactions at the world's highest available energies--the colliding proton beams in the intersecting storage rings (ISR) at the European Center for Nuclear Research (CERN) and, eventually, in the colliding electron-positron facility (PETRA) now under construction at the German Electron Synchrotron (DESY) Laboratory in Hamburg, West Germany. The latter possibilities are perhaps the most exciting, since they hold forth the promise of sufficient energy to observe, jointly, the electromagnetic and the weak interactions, and thereby to explore experimentally the recent new theoretical ideas suggested by the heretofore elusive unified theory of the weak, the electromagnetic and, possibly, the strong interactions.

During the first week in January 1977, the linear accelerator group organized the Bates Mid-winter Workshop, at which the Bates experimenters, both from M.I.T. and from the many user groups, gave intensive consideration to plans for effective utilization of a new Bates experimental area, whose construction has been authorized by the Energy Research and Development Administration (ERDA). During June 1977, members of the accelerator group and of the theoretical division jointly conducted a month-long workshop on Intermediate Energy Electromagnetic Interactions with Nuclei, to consider the longer-term prospects of the field. In addition to members of the Nuclear and Theoretical Division, approximately 25 visitors from all the major groups and installations involved in this field throughout the world participated in the June workshop.

FACULTY

The following faculty members received promotions during the year: Ulrich J. Becker, Eric R. Cosman, Thomas J. Greytak, and Roman W. Jackiw were promoted to Professor; Associate Professor David E. Pritchard received tenure; Kenneth Brecher, Marc A. Kastner, and Ernest Moniz were promoted to Associate Professor.

New appointments were as follows: Jeffrey Goldstone and Miklos Porkolab were appointed Professors; Margaret H. Weiler was appointed Assistant Professor, and Carroll W. Creswell was appointed Instructor.

Visiting Professors included Jens Als-Nielsen, Keith Boyer, T.S. Chang, Carl Spight, Joseph Wenner, and Dieter Zimmermann; Claudio Rebbi was Visiting Associate Professor.

On leave during spring term were Professors Pritchard, George B. Benedek, Francis E. Low, and Louis S. Osborne. Resigning were Associate Professor Jochen Heisenberg, Assistant Professor James E. Wolfson, Instructor Karl Van Bibber, and Senior Research Scientist William U. Walton.

Professor Samuel C. C. Ting was appointed to the Thomas Dudley Cabot Institute Professorship. Institute Professor Emeritus Victor F. Weisskopf was named first recipient of the Ludwig-Boltzmann Prize of the Austrian Government for special service to Austrian research and research policy. Institute Professor Emeritus Bruno B. Rossi was awarded the Rumford Premium of the American Academy of Arts and Sciences.

Named Fellows of the American Academy of Arts and Sciences were Professors Goldstone and Lee Grodzins. Professor Goldstone was also elected a Fellow of the Royal Society of London. Guggenheim Fellowship awards were made to Professors Jackiw and Alan H. Barrett.

HERMAN FESHBACH

Spectroscopy Laboratory

The Spectroscopy Laboratory is dedicated to advancing our knowledge of the structure and dynamics of atoms and molecules and the properties of liquids and solids, utilizing the techniques of modern spectroscopy. These techniques include the use of lasers and high resolution spectrometers. As an interdepartmental laboratory, the Spectroscopy Laboratory encourages participation and collaboration among staff members in various disciplines of science and engineering. This past year there has been participation from the Departments of Biology, Chemistry, Physics, and Civil Engineering.

The Laboratory has had a long and distinguished career and has played an important role in areas of classical spectroscopy, including the detailed studies of atomic spectroscopy which led to the M. I. T. Wavelength Tables, and the development of techniques for making optical diffraction gratings of unequalled size and resolution. There is a new challenge to redirect the efforts of the Laboratory and bring it into the era of modern spectroscopy, especially utilizing powerful laser saturation techniques. The progress made during the past year reflects these goals.

Professor Alexander Rich continues to explore the three-dimensional structure of yeast phenylalanine transfer RNA, which plays a central role in protein synthesis. The most recent efforts have been directed towards the refinement of the X-ray diffraction interpretation in order to make a better fit with the observed diffraction data. This has allowed refining the molecule to the point where the residual factor has fallen to 22 percent. Because of this, the difference Fourier map now allows visualization of the magnesium ions and water molecules, as well as the spermine molecules in the lattice, which play an important role in stabilizing the conformation of the molecule.

A more recent project seeks to determine the three-dimensional structure of the gene 5 protein, a protein molecule which comes from the bacteriophage fd and functions to unwind the double helix of DNA. The calculated three-dimensional Fourier electron density map at 2.3 Å resolution looks promising enough so that it is being installed in the Spectroscopy Laboratory's optical comparator. It will then be used to attempt a fitting of the polypeptide chain to the electron density map.

Professor Richard C. Lord and his students, Dr. G. D. Lee and Dr. G. Forrest, have extended their studies of far infrared absorption and biological Raman spectroscopy, respectively, to a halogenated derivative of cyclohexene and to cyclic nucleotides, particularly cyclic AMP.

In November 1976, Professor Lord received the Ellis R. Lippincott Medal, jointly awarded by the Optical Society, Society for Applied Spectroscopy, and Coblentz Society, for his work in infrared and Raman spectroscopy.

A grant from the National Science Foundation to Professor Lord, and co-investigators Professors Robert W. Field, James L. Gole, James L. Kinsey, John Ross, Robert J. Silbey, and Jeffrey I. Steinfeld, has permitted establishment of a state-of-the-art tunable laser facility in the Spectroscopy Laboratory. Most of the major equipment, including several high-power argon-ion and c.w. dye lasers, has been installed. This new facility is being supervised by Dr. Phillip Cummins, a postdoctoral research associate.

The major users are currently Professors Field and Steinfeld, who are collaborating on an experiment involving an optically pumped molecular iodine laser. Properties of I_2 molecules very close to their electronic ground state dissociation limit are being studied. Other experiments include optical-optical double-resonance spectroscopy of such systems as NO_2 , thiophosgene, symtetrazine, BaF, CaO, and rare-earth monoxides.

Other members of the Department of Chemistry have availed themselves of this facility. Professor Mark Wrighton has examined the saturation and damage thresholds of his photoelectrochemical cells, using high power density c.w. ultraviolet radiation from the argon ion laser. Professor Edward Solomon is using the tunable lasers to record electrically induced linear dichroism spectra in low-temperature solids. Professor H. Gobind Khorana is planning to use the high-power ultraviolet sources to carry out selected photochemical conversions.

In related work, using tunable infrared lead-salt diode lasers, Professor Steinfeld and his students have carried out rotational analyses of several infrared absorption bands of vinyl chloride, an asymmetric rotor.

Professor Ali Javan and his co-workers have made progress in several areas of laser spectroscopy. Using a multiline laser, work has continued on the experiment to excite high vibrational levels in the D_2O molecule. A study is being made of the redistribution of energy from one molecular energy level to the rest of the molecular energy manifold. An independently controllable, multifrequency CO_2 laser has been designed and constructed to provide the many frequencies needed for on-resonance multiphoton excitation. The output of the laser is a col-linear combination of preselected CO_2 laser lines. An atmospheric CO_2 TEA laser was inserted into the laser cavity and forced to oscillate on the preselected transition in order to provide high power intensities.

An experiment to observe RF-laser double resonances in N_2O is under way. The technique utilizes RF magnetic dipole transitions among the N_2O hyperfine components to change the anisotropy of the laser induced 4-5 μ fluorescence. In order to observe fluorescence anisotropy one must work at very low pressures ($\ll 1 \mu$ torr). In addition to this technique, one may observe

N_2O hyperfine structure by utilizing crossing resonances. A preliminary investigation in NH_3 has confirmed the idea that the forward and backward going traveling waves should have crossed linear polarizations. The NH_3 hyperfine structure has been observed with good resolution using this technique.

Work was completed on the hot band absorption studies in nitric oxide. A tunable 5μ spin-flip Raman laser was used to measure Δ -doublet splitting in NO. From this data it was possible to determine the vibrational dependence of the Δ -doubling constants. In addition, some observations were made of Doppler-free two-photon absorption in NO. With this technique, band widths of 25 MHz (FWHM) were achieved. Both of these studies were done using a Pyrex capillary tube as a waveguide. This makes it possible to obtain the necessary high laser intensities over long interaction length.

A new precise ($1:10^8$) determination of the speed of light has been made, using the precision long arm scanning Michelson interferometer developed over the past few years. This interferometer, which is capable of measuring absolute wavelengths to within several parts in 10^9 in the 10μ spectral range and to within several parts in 10^{11} in the visible, promises to be an important new general spectroscopic tool.

Professor Michael Feld's research has progressed along several lines. A study has been completed to explore energy absorption and energy transfer by vibrational (V-V) collisions following intense laser excitation. A theoretical model was derived which predicts that under appropriate conditions several quanta per molecule can be absorbed in vibrational energy. This was confirmed using a pulsed CO_2 laser to vibrationally heat $^{13}CH_3F$. These findings are basic to the use of molecular gases as energy storage media. Furthermore, a complete knowledge of the energy distribution of vibrationally hot but rotationally cold gases opens interesting possibilities for achieving laser oscillation and for studying chemical reactions in excited vibrational states.

A new set of studies to observe narrow laser-induced saturation resonances in the time-delayed mode is under way. The experiments study optical mutation and free induction decay in a Doppler-broadened transition, by observing the transmission of a weak probe field resonating at a coupled transition. These techniques open new possibilities for direct detailed observations of relaxation phenomena and effects of velocity dephasing in gases, and provide an experimental method for separately studying the effects of population saturation and Raman-type processes in three level systems. The initial experimental observations, in NH_3 , give a value for the population decay of the excited vibrational state. Related steady-state studies have yielded information about NH_3 reorientation collisions.

The quantum mechanical features of optically pumped lasers are being explored in far-infrared transitions of CH_3OH .

A laser-nuclear experiment now in progress aims at measuring properties of excited nuclei with lasers in the visible part of the spectrum. This is possible because the orientation induced in the atomic levels by the laser gives rise to a corresponding nuclear orientation because of coupling through the hyperfine interaction. At the atomic resonance peak, a highly anisotropic distribution of γ -rays is expected, and this anisotropy acts as a very sensitive indicator of the resonance condition. The initial experiments are being done on a metastable level of the Ba-137 nucleus with the electronic levels pumped at 553 nm by a single-mode tunable dye laser. Recently, hyperfine structure Lamb dips have been observed in ground state barium atoms. This project has been undertaken jointly with Dr. Dan Murnick of Bell Telephone Laboratories, who was Visiting Associate Professor during the past year.

Research on superradiant emission in an extended, optically thick sample continues. Processes and phenomena which limit the N^2 behavior have been explored. A set of criteria for superradiant emission in X-ray systems has also been developed.

Dr. Lon Hocker has used the 11m. eschelle spectrograph for high-resolution measurements of nine laser lines in neutral fluorine. The observed broadening has been found to result from an anomalous velocity distribution of the upper state fluorine atoms fed by a dissociate state of HeF. Measurements of these lines have also yielded new values for the hyperfine splittings of several levels in neutral fluorine.

Viewed in perspective, the past year has been one of renewal and change. The new spirit was typified by last summer's meeting at Talbot House, where the professors and students who work in the Laboratory discussed their research and got to better know one another. In the coming year we look forward to increased collaboration across departmental lines and new sources of funding.

MICHAEL S. FELD

George R. Wallace, Jr. Astrophysical Observatory

The George R. Wallace, Jr. Astrophysical Observatory is an active teaching facility as well as a sophisticated scientific installation. It consists of two telescopes (one 16-inch and one 24-inch) which are housed in separate domes, a computer facility designed to control the 24-inch and process data on-line, and a support building.

The Observatory Steering Committee is appointed by the Dean of the School of Science and chaired by Professor Herbert S. Bridge of the Department of Physics. Committee members are Professors Hale V. Bradt, Bernard F. Burke, Rainer Weiss, and Assistant Professors Susan G. Kleinmann and Edward L. Wright, all of the Department of Physics, and Professor Gordon H. Pettengill of the Department of Earth and Planetary Sciences. This body prescribes observatory policy and determines the direction of observatory development.

Dr. Thomas B. McCord, who served as the Director of the Observatory since its inception, resigned during this year to accept a position at the University of Hawaii. The Steering Committee is actively seeking a replacement and also a replacement for Michael Brookes, the Chief Engineer of the Observatory, who has returned to his former position in England. Andrew Tomer continues to function as site manager and as technical assistant.

During fall, 1976, the 16-inch and 24-inch telescopes were regularly used by students enrolled in subjects 12.111 Survey of Astronomy I, 12.113 Astronomy I, and 12.143 Experimental Optical Astronomy. Students enrolled in subsequent subjects 12.112 Survey of Astronomy II and 12.114 Astronomy II during spring term frequently used the facility as well. Examples of student research projects carried out with the 24-inch telescope were: search for IR radiation from X-ray sources, measurement of IR excess in F and G type stars; and measurements of eclipsing binaries in Monoceros. Several research projects were also carried out with the 16-inch telescope.

The Wallace Observatory has been and will continue to be used for development and testing of new instruments which are later used at major observing facilities around the world. In addition the number of research projects planned for the 24-inch telescope during the coming year shows a significant increase.

HERBERT S. BRIDGE

Vice President and Dean of the Graduate School

The annual reports for the Medical Department -- including those for the Environmental Medical Service, Radioactivity Center, and Division of Laboratory Animal Medicine -- and for the Registrar follow my introductory comments and my own reports on the Graduate School and the Institute's several housing programs.

DEAN OF THE GRADUATE SCHOOL

Graduate Student Financial Support

The graduate student who wrote one of the lead stories for the special "Orientation '77" September issue of the Graduate Student Council newspaper, The Graduate, summed up in the proverbial nutshell one of the foremost concerns I share with those of my colleagues most intimately involved with our graduate program. The anonymous author wrote: "Welcome to M.I.T. Congratulations on your admission and the decision to attend one of the finest, most prestigious institutions of higher learning in the world. . . . Now that you're here, how are you going to pay for it?"

Financial projections are indeed pessimistic. Tuition, fees, and living costs continue to grow at faster rates than do most fellowship or assistantship stipends, and, to compound the problem, the number of positions providing scholarship and/or living cost support decreases from year to year. Nevertheless, M.I.T. continues to buck certain national trends in shrinking graduate enrollments so that, across the board, the Institute's academic departments have attracted increasing numbers of highly qualified students. The statistical information set forth in Tables I through IV illustrates the challenge we face.

From the late 1940s to the late 1960s, the infusion of Federal funds for research in many areas encouraged a rapid expansion of graduate enrollment. Although this growth was desirable and in many ways essential to M.I.T.'s attainment of world leadership, growth in endowed funds for graduate student support has not been sufficient to ensure an adequate level of independent support for these students.

An M.I.T. graduate education is expensive, even in comparison with other top rated private universities, since those institutions typically have greater endowed resources for graduate student support and, in addition, their tuition policies enable them to charge reduced tuition rates to graduate students who have completed formal course work. Thus, although M.I.T. provides unparalleled teaching and research programs, the high costs of these programs and our limited ability to provide graduate aid result in a situation which requires that graduate students entering M.I.T. be prepared to face serious financial obligations over the several years of their graduate programs.

While we can and should be extremely proud of the quality of M.I.T.'s graduate education and research programs, we are also keenly aware of our problems in seeking to provide adequate support for the talented young people who make up our graduate student body. The goal of acquiring additional funds for graduate student assistance must be one of highest institutional priority.

Committee on Graduate School Policy

During 1975-76 the Committee on Graduate School Policy established several sub-committees on several areas of policies and procedures. During 1976-77 the C. G. S. P. heard and debated the reports of these sub-committees with the following results (reported in brief):

Financial Support Structures - The method of allocation to departments of general and endowed funds available to the Graduate School was generally endorsed. A new allocation scheme and method of utilization of Federal funds available for needy US students under the College Work-Study Program was proposed. Complete details of implementation are still under formulation.

Tuition and Fee Policies - Significant changes in the Institute's current policy of charging full tuition for each student making progress toward the graduate degree were debated at length with no resolution. Subsequently, dissatisfaction with our undergraduate tuition policy and subject weighting caused the joining of the graduate and undergraduate issues. The Chancellor currently plans to conduct an all-Institute review during 1977-78.

Foreign and Special Students and Related Programs - A "tightening up" of admissions policies and registration procedures for special students has been adopted for implementation during 1977-78. A new program for teaching of English as a foreign language was established as a permanent program within the foreign language section of the Department of Humanities. Certain other issues such as loan programs for foreign students continue under active study.

Thesis Policies - The past cumbersome approval procedure for thesis in absentia was modified to require only administrative approval within the Graduate Office. New review and monitoring procedures for deposit of theses in the libraries were developed and implemented.

Subjects and Performance Evaluation - Clarification of authorization for the use of the grades of I (incomplete) and J (grade deferred) was achieved. Considerable attention was focused on grade inflation, preparing the way for the graduate portion of the current study under way by the all-Institute committee on grading. This sub-committee continues to act with power for the C. G. S. P. in approving proposed new subjects of instruction offered for graduate credit. Thus, the sub-committee continues to be concerned about the distinction or lack thereof in "graduate" and "graduate A" subjects.

In addition to conducting the routine business of grades review and certification of graduate degree candidates, the C. G. S. P. also:

- 1) Provided for regular student membership (from the Graduate Student Council) at all meetings;
- 2) Recommended to the faculty that: a) new Ph. D. and Sc. D. degrees in Medical Engineering and Medical Physics be awarded through the new Division in Health Sciences and Technology, b) the experimental S. M. program in Course XXV Interdisciplinary Science be continued for an additional three years, a total of six years, c) three Engineer's degrees in Ocean Engineering be discontinued.
- 3) Lent support to an Engineering School proposal to cooperate with Mount Holyoke College in developing an experimental program to interest more liberal arts college graduates in pursuing graduate work in engineering.
- 4) Approved new admissions and application forms and procedures for graduate students. (A new reply form asks the candidate to state his/her reasons for accepting or rejecting M. I. T.'s offer of admission at the time the candidate replies to the offer. Through this survey, which will augment those conducted by some departments, we hope to learn more about our strengths and weaknesses as perceived by potential incoming students.)

- 5) Endorsed the formulation of a number of School-wide subjects in Engineering and of a new Engineering Internship (co-op) Program.

Finally, the staff of the Graduate Office met during the academic year with C.G.S.P. representatives for informal, off-the-record discussions of mutual goals and problems in three dinner meetings -- one for all Engineering departments, one for all Science departments, and one for departments in the "three small Schools." The quality of the exchange was uniformly high. The response of all concerned was so positive that I plan to suggest a continuation of this program next year -- in some cases with student representatives from the Graduate Student Council.

Although discussion at these meetings ranged over many topics, two were of particular concern: graduate education for women and graduate education for minorities. I believe it is appropriate to expand somewhat on our past record as we seek to do our share and more on these challenging and very important needs.

Graduate Women

Although from 1975-76 to 1976-77 the number of graduate women enrolled grew 12 percent (Table I), the total fraction of women in the graduate body grew by only one percentage point (from 14 percent to 15 percent). No major changes have occurred in the past several years in the distribution of women throughout the five Schools. In 1976-77 the percentages of total enrollment were:

Architecture and Planning	33%
Humanities and Social Science	24%
Sloan School	19%
Science	18%
Engineering	6%

Thus, one of our greatest challenges remains that of attracting more women to the engineering and physical science fields where the largest number of our total graduate student population is enrolled. In an effort to recruit more women to Engineering, the Committee on Engineering Education in the School of Engineering has been working with Mount Holyoke College to develop a Master's program in Engineering which would better prepare women in liberal arts colleges for admission to engineering graduate schools. At the same time, this program hopes to alert women to career opportunities in the engineering field. This program is currently in early development stages and involves primarily Mount Holyoke, Wellesley, and M.I.T.

The Institute received almost 1,200 applications from women this year; this represents a 44% increase from 1973 to 1976 with a corresponding increase of 15 percent for male applications. In an effort to increase the pool of women applicants, the Graduate School Office developed and mailed about 400 posters depicting "Women in Graduate Study at M.I.T." to leading universities throughout the United States, particularly to those institutions which include undergraduate training in mathematical, scientific, and engineering fields.

A steady increase in the number of degrees awarded to women has continued. (See Table IIa.) However, the majority of women are enrolled in departments such as the Sloan School, Architecture, and Urban Studies, whose graduate programs lead primarily to Master's degrees. The number of doctoral degrees awarded to women remains small: eight doctoral degrees in Engineering, none in the Sloan School, 10 in the School of Humanities and Social Science, two in Urban Studies, and 31, the majority, in the School of Science (18 percent of Science doctoral degrees). Note that these statistics do not include Engineer's degrees which are often awarded as simultaneous degrees and to date very few women have received these degrees.

Women graduate students, no less than men, are being affected by the decrease in financial aid for graduate education in the face of the increasing tuition and other costs of a graduate education. This situation may have a disproportionate effect on M.I.T.'s graduate women in that many of them are enrolled in those departments whose financial resources are most limited.

For the fourth year the Graduate School Office awarded Ida M. Green fellowships to seven incoming graduate women from the fund which has been set up by Cecil and Ida Green for this purpose. In addition, one continuing graduate woman was awarded a Collamore-Rogers Fellowship from endowed funds given to M.I.T. to help women in their graduate studies. Such funds to support graduate women are important in encouraging and attracting women to M.I.T. However, like all M.I.T. endowed funds, income from them is limited and as costs increase the number of individuals who can be supported by these funds must necessarily decrease. In addition, this year M.I.T. women have been the recipients of fellowship awards from IBM, Xerox, and Arthur D. Little, who have established special fellowship programs for women and minorities who are studying in science and engineering fields. Hopefully as their numbers increase women will become more competitive for research and teaching assistantship money within departments.

M.I.T. women continue to be successful in winning graduate fellowship support in national competitions. This year three M.I.T. graduate women won dissertation fellowships from the American Association of University Women, and of the 11 Danforth Fellows studying at M.I.T. this year three were women. There were 18 National Fellowship Fund recipients enrolled in M.I.T. graduate programs during fall, 1976, including nine women. Other women students received fellowships from the National Science Foundation, the National Institutes of Health (N.I.H.), Hertz Foundation, Wellesley College, and Bell Laboratories for their graduate work at M.I.T.

Women have always valued an M.I.T. education and degree. However, in some instances their isolation in certain research areas and their difficulty in finding mentors and role models has put a certain personal cost on the value of their education. During the past year the Graduate School Office has sponsored various activities in an attempt to reach out to graduate women and bring them together.

Associate Dean Jeanne E. Richard assembled a group of graduate women to plan a welcoming party for incoming graduate women. This event took place in the Cheney Room as part of the orientation activities for graduate students planned by the Graduate Student Council. Continuing graduate women as well as faculty and staff acted as hostesses for the new women. This group also put together a brochure entitled "M.I.T. Resources of Interest Primarily to Women Graduate Students" and distributed it as part of a women's packet during orientation week.

During the summer a group of women staff and graduate students met with Dean Richard and planned a series of discussion groups. These were held biweekly during the fall and spring terms and served to help women graduate students become better acquainted with each other and to exchange M.I.T. experiences.

In the fall, prior to vacation, a Thanksgiving party was held in the Cheney Room for women graduate students, faculty, and staff. In April the fourth annual program for prospective graduate students to visit their M.I.T. departments and meet current students was held. Over 200 people participated in informal department gatherings followed by a very successful reception at the President's House hosted by Mrs. Laya Wiesner.

Graduate Minorities

At the national level, access for blacks to graduate and professional schools has worsened over the last two years. According to a recent study by Dr. Tollet of Howard University published in the book, More Promise Than Progress - A Continuing Assessment of Equal Educational Opportunity for Blacks in US Higher Education: 1974-75, there was an 8 percent

decrease in the number of blacks in graduate and professional schools in 1974 and a similar decrease in 1975. Blacks are better represented in community colleges and private vocational schools than in four-year colleges and universities.

While minority graduate student enrollment has declined nationally, M.I.T.'s minority graduate student enrollment continues to increase, we believe primarily as the result of the strong commitment and active minority recruitment programs in the following departments: Architecture, Urban Studies and Planning, Management, Physics, and Economics. The minority graduate student enrollment for fall term of 1976 increased 15.6 percent over the previous year's enrollment, from 154 to 178 students (Table I), and the numbers receiving graduate degrees are rapidly increasing (Table IIb).

Our focus for the next few years at M.I.T. will be to increase our recruiting and to support joint efforts with faculty in the Schools of Engineering and Science where minorities make up only 2 percent and 3 percent respectively of the total enrollments. At the same time we will try to maintain our momentum and progress in the other departments. Specifically, we hope to launch a comprehensive recruitment program during academic year 1977-78 involving M.I.T. faculty in those departments that currently have low enrollment of minority graduate students. We would like to triple our enrollment of minority graduate students in the School of Engineering by the fall term of 1978-79. Such a massive effort will require cooperation from the departments, financial assistance from the Institute, and time and commitment on the part of individual faculty members. A number of departments, interested alumni, and several concerned individuals inside and outside of the Institute have indicated that they believe our goal can be achieved and are willing to help.

In addition we have become active participants in several programs that should also help to increase our minority enrollment in Engineering over the next three years.

In 1976, 19 universities and eight research centers founded the National Consortium for Graduate Degrees for Minorities in Engineering, Inc. The Consortium's headquarters are located at the University of Notre Dame because of its central location in the country and the strong support given to the program from Father Hesburgh at Notre Dame. M.I.T. is one of the founding members, and Associate Dean John B. Turner is a member of the Board of Directors.

The Consortium's objective is to increase the number of minority men and women granted advanced degrees in the field of engineering. To meet this objective the Consortium will provide summer employment/educational programs in which minority undergraduate students will have three summers of work experience at participating research centers and up to two years of graduate education at participating engineering schools. It is hoped that eventually 100 minority students who are in their junior year of undergraduate study will be selected for the program each year. Each school makes its own graduate admission decisions and contributes the first \$500 of tuition for each student admitted. Tuition costs between \$500 and \$2,500 are shared 75 percent by the Consortium and 25 percent by the university. All tuition costs over \$2,500 are paid by the university. The Consortium will also provide a \$3,000 annual stipend to these students while they are attending a participating graduate school.

The Consortium is off to a good start having recently received a grant of \$450,000 from the Alfred P. Sloan Foundation for "start up" money to supplement the annual contributions of \$15,000 each from the 10 participating laboratories. The program recruited its first group of students during the 1976-77 academic year, admitting 30 students from the 73 applications received from minority college juniors. M.I.T. placed the largest number (6) of students in the program. Since research laboratories are very interested in attracting minority engineering students from M.I.T. upon graduation, we were not surprised by the fact that all of our students who applied were admitted to the program.

We also have our own summer work and study program for minority students at Lincoln Laboratory. Starting in summer, 1975 Lincoln Laboratory has provided employment for 10 students each year who have successfully completed one year of undergraduate study at a predominantly black institution and whose major or intended major field is in Electrical Engineering or Physics (applied). Students so selected may be reappointed in subsequent years; i. e., the summers following their second and third years of study, provided that they have successfully completed that year of study and are still pursuing a degree in Electrical Engineering or Physics. Students in the program are assigned to positions in the Laboratory as technical assistants and paid a weekly salary. They are also expected to attend classes established for them and presented in the Laboratory or at the M. I. T. campus under the auspices of M. I. T. 's academic departments and Lincoln Laboratory.

The students in the program have progressed well and Lincoln Laboratory hopes to continue the program indefinitely. There will be 21 students in the program during summer, 1977; 10 sophomores, 8 juniors, and 3 seniors. We in the Graduate School Office are very interested in the program's development and success, for we feel that this arrangement with the black colleges is a viable means of generating a large number of black students to pursue future graduate study at M. I. T. The benefits of the program to the student are immense. The exposure to varied talent, equipment, laboratory projects, as well as the exchange of technical knowledge and information between the student and scientist are invaluable aids in enhancing the educational development and career of the student.

In addition to these national efforts focused on engineering, we have joined two other national efforts to increase minority representation in graduate programs.

We are one of the founding members of an informal organization called the Ad Hoc Consortium on Minority Graduate Education formed in mid-1976. Senior administrators at several institutions of graduate education participated in discussions leading to the concept of "institutional bloc-grants" and to a national proposal to support and partially finance efforts to enroll more minority students at these institutions. The graduate institutions involved in the Ad Hoc Consortium (Berkeley, Brown, Cornell, Harvard, Johns Hopkins, Michigan, Minnesota, M. I. T., North Carolina, Notre Dame, Ohio State, Princeton, Stanford, U. C. L. A., Vanderbilt, Washington, Wisconsin, and Yale) are hopeful that Congress will appropriate funds to start the program in fiscal year 1978.

Another group, The Cooperative Minority Student Recruitment Program, composed mostly of black associate deans from 20 of the leading graduate institutions in the country, met at the University of Pennsylvania in February 1977 and agreed to exchange the names of their minority seniors and juniors. The exchange of names is intended to recruit more minority students to the participating graduate institutions by minimizing the difficulties of identifying minority students nationally as well as reducing the cost of recruiting trips to these institutions. The students' permission was sought before their names were placed on the exchange list. By April 1977 over 1,200 names of minority juniors were exchanged by these 20 institutions.

Minority students do have different social, cultural, and economic lifestyles from those of the majority student body at M. I. T. Since we recognize the importance of enriching student life beyond the laboratory and classroom, we have supported activities for minority graduate students to help them make an easier transition to M. I. T. and at the same time extend their cultural and social heritage at a place where they are only 4 percent of the total graduate student enrollment.

With this in mind, Dean Turner established a Minority Graduate Student Orientation Program in 1975 which has now become an annual event. The Minority Orientation Program helps to welcome and introduce the new minority graduate student to M. I. T. as well as to supplement the information that students receive at the larger Graduate Student Council Orientation Program.

In August 1976 the newly formed Black Graduate Student Association, in collaboration with the Graduate School Office, published a booklet on black student activities at the Institute and in the Cambridge/Boston area. The booklet had information from where to go for institutional services, i. e., counseling, financial support, medical help, etc., to where to get a haircut or some soul food. There was a list of black graduate students and their departments as well as a roster of black faculty and staff at M. I. T.

During the year a number of social, cultural, and academic activities were planned and implemented by the Black Graduate Student Association and Dean Turner's office. Some of the activities were: minority Graduate Student Orientation Program; retreat at Talbot House; soul food sale; reception for black faculty members; minority graduate student seminar series with such speakers as Dr. Alvin Poussaint, Professor Willard Johnson, Clarence Johnson, Abraham Ford, D. L. Chandler; "Ebony Affair," a semi-formal cabaret dance with more than 450 people attending; pot-luck dinner at Dean Turner's home; awards program for black students; reception for minority students and graduates at Commencement; and Fisk Jubilee Singers at Symphony Hall (co-sponsorship).

Study Abroad

Interest in study abroad by our graduate students has traditionally been limited, however this year the Foreign Scholarship Committee received a substantial increase in the total number of applications over the previous year. This past year the committee reviewed 19 applications for graduate study abroad for 1977-78. Twelve applications were for the Fulbright-Hays program, seven for the German Academic Exchange Service (DAAD) Scholarship, and one for the Winston Churchill Foundation Scholarship. Of the 12 applicants for Fulbright-Hays grants, three passed the National Screening Committee's preliminary application stage and went on in the competition to win grants. Irwin L. Collier, Jr. of the Department of Economics won an award for study in Germany; Elizabeth R. Leeds of the Department of Political Science, for study in Portugal; and Richard J. Samuels of the Department of Political Science, for study in Japan. Mr. Samuels also won an Office of Education Fulbright-Hays grant which will enable him to study in Japan for 16 months.

The DAAD offered M. I. T. two direct scholarships this year instead of one as in previous years. Although the committee nominated two outstanding students for the scholarships, the DAAD felt that one candidate did not have sufficient language preparation for his proposed study. Therefore, Cynthia Koelker of the Department of Biology, was the only DAAD Scholarship recipient for 1977-78. Our nominee for the Winston Churchill Foundation Scholarship was unsuccessful in the national competition. The committee would like to see a larger pool of applicants for the Churchill Scholarship and plans to make a major effort this fall to alert seniors in the sciences and engineering to this opportunity for study abroad.

Staff

Finally, I am pleased to report that the significant contributions of Deans Richard and Turner were recognized during this year in their promotions. Jeanne Richard is now Associate Dean, Administration and Dr. John Turner is now Associate Dean, Program Development. To them and to the other members of our small staff, I must acknowledge with sincere thanks their hard work and strong support and teamwork over the year.

HOUSING

As I reported last year economic problems have continued to plague us as we seek to provide additional housing resources for the Institute community.

The Northgate Community Corporation, a not-for-profit corporation wholly owned and controlled by the Institute, was formed several years ago to make available good moderate-cost housing off campus for students and staff. After some successful years, the corporation found itself unable to meet inflation driven rising operating costs within the hostile economic environment created primarily by excessively restrictive rent control. Thus, the corporation has found it necessary to divest as rapidly as possible. By this action the corporation will incur significant capital losses but also reduce operating losses which had reached intolerable levels. During the latter part of this year the decision was reached to transfer the ownership and operation of the few remaining properties to the Institute and to dissolve the Northgate Community Corporation.

Economic limitations have also resulted in our being unable to initiate new student housing programs on campus. Overcrowding in the undergraduate houses is now reaching the point where it is clear we need an additional house for about 300 students. Similarly, demand for married student housing far exceeds the supply. Thus, we now also need an additional apartment structure for married students. The difficulty, of course, is that even with the most favorable financing available, the new construction costs are such that these projects cannot be financially self-sustaining at rental levels which students can be expected to pay. The solution, of course, is to identify large-scale gifts to provide the major fraction of the capital costs needed. The unfortunate fact is that, while such gifts have been high priority items in our current Development Program, we have not yet been successful in meeting this critical need.

Last fall the target for admission of first-year students entering in September 1977 was set at 1,000, dictated by housing limitations. We are currently estimating this class will be 1,075 to 1,100 persons. Although it is encouraging to know that our appeal is such that the fraction of students offered admission who accepted our offer increased dramatically, we are faced, nevertheless, with a mini-crisis in locating adequate housing. Our solution, a step taken with considerable reluctance, is to convert Random Hall into a new Institute house to house about 100 undergraduates beginning next September. This is a property located on Massachusetts Avenue which was acquired and operated by Northgate as a facility primarily to house short-term transient persons affiliated with the Institute.

It was leased by the Institute for a few years some time ago to house an overflow of undergraduates but returned to Northgate when new housing was opened on campus. In the current instance, the Institute will acquire the property and operate it for the foreseeable future as an undergraduate Institute house. Every effort will be made by the Housing and Dean's staffs to provide good, albeit not ideal, accommodations and a good support program.

On the brighter side, I am pleased to report that our program to create two new independent residences from another older structure on Massachusetts Avenue shows every indication of being completed and in full-scale, high-spirited operation by this coming fall. One residence is for about 50 undergraduate women and the other for about 50 undergraduate men. The undergraduate men and women and the alumnae and alumni groups who have worked so diligently on this imaginative project deserve our sincere thanks. A special note of appreciation is due James H. Eacker, Class of 1955 who, as our consultant, provided the day-to-day management skill and expertise to guide the project through some difficult problem areas.

MEDICAL DEPARTMENT

Last year I reported the tragic loss of Dr. Albert O. Seeler, Medical Director for many years, and upon the process then under way to identify his successor. Shortly after the beginning of the academic year 1977-78, the Search Committee completed its national search and recommended to the Medical Administrative Board that Dr. Melvin H. Rodman be appointed Professor of Medicine, Medical Director, and Head of the Medical Department.

Dr. Rodman had served for many years as Dr. Seeler's Associate Director and, therefore, was very familiar with the problems and challenges. Nevertheless, he soon found himself faced by an enormous but wonderful problem. As he reports below, the Institute found it possible this year to move ahead on the Department's long-cherished objective to construct a new home. Dr. Rodman and his associates have risen to this and other challenges with great enthusiasm, dedication, and competence.

KENNETH R. WADLEIGH

For simple comparison with data for 1975-76, the following statistical information for 1976-77 is presented in the same format. Numbers in parenthesis indicate the changes from 1975-76 to 1976-77.

Table I REGULAR GRADUATE STUDENT ENROLLMENT, FALL TERM 1976

	Foreign*	Women	Minority**	Total
School of Architecture and Planning	56(+3)	99(+10)	59(+9)	288(+27)
School of Engineering	604(+10)	110(+19)	44(+6)	1774(+50)
School of Humanities and Social Science	72(+13)	69(+9)	27(-3)	285(+15)
Sloan School of Management	96(-2)	79(+5)	17(+8)	396(+60)
School of Science	231(-2)	189(+16)	31(+3)	1031(+19)
TOTAL	1059(+22)	546(+59)	178(+23)	3774(+171)

* Includes Canadians

** Includes Black Americans, Puerto Ricans, Mexican-Americans, and Native Americans

Table II GRADUATE DEGREES AWARDED, 1976-77

Advanced Degrees Conferred	M. C. P., M. Arch., M. Arch. A. S.	S. M.	Engineer	Sc. D.	Ph. D	Total
September 1976	14(+ 3)	172(+17)	16(+ 6)	14(- 1)	111(+10) 3WH*	330(+35)
February 1977	15(- 8)	220(+25)	27(+ 3)	19(- 7)	84(-33) 5WH*	370(-20)
June 1977	63(+11)	487(+61)	48(-12)	20(+ 1) 1WH*	120(+19) 2WH*	741(+80)
TOTAL	92(+ 6)	879(+103)	91(- 3)	54(- 7)	325(- 4)	1,441(+95)

Table IIa GRADUATE DEGREES AWARDED TO WOMEN

	1975-76	1976-77
Master's Degrees	93	145
Doctoral Degrees	32	51

Table IIb GRADUATE DEGREES AWARDED TO MINORITIES

	1975-76	1976-77
Master's Degrees	29	45
Doctoral Degrees	7**	8

* Woods Hole Oceanographic Institution

** A total of 8 Doctoral degrees was awarded to minorities in the 15-year period prior to 1975-76.

Table III
A "SNAPSHOT" OF GRADUATE STUDENT SUPPORT "FULL AWARDS"

The following sources provided at least full tuition support for graduate students during fall term, 1977. Total regular graduate enrollment was 3,774.

	Numbers of Students	Percent total Enrollment	Change from 75-76	Percent of Difference
FELLOWSHIPS AND TRAINEESHIPS AWARDED BY M. I. T.				
NIH and Other HEW Traineeships	130		-38	
NSF Energy Traineeships	27		+5	
Energy Research and Development Administration Traineeships	14		0	
HUD Minority Intern Program	8		-2	
HEW Domestic Mining and Mineral Fuel Traineeships	8		+6	
Environmental Protection Agency Traineeships	3		-4	
M. I. T. Endowed and Other Fund Fellowships	220		+12	
Industrial and Foundation Fellowships	109		+16	
National Defense Education Act Traineeships	0		-3	
Department of Transportation Traineeships	0		-2	
SUBTOTAL	519	14%	-10	-1%
FELLOWSHIPS AWARDED BY SPONSORS TO M. I. T. STUDENTS				
NSF Graduate Fellowships	142		-6	
NIH Fellowships	4		+1	
Hertz Foundation Fellowships	22		+3	
Department of Labor Dissertation Grants	0		-7	
Environmental Protection Agency Fellowships	0		-1	
SUBTOTAL	168	5%	-10	0%
STUDENT ASSISTANTSHIPS				
Research	1,264		-102	
Teaching	486		+48	
SUBTOTAL	1,750	46%	-54	-4%
SPONSORED STUDENTS				
Many students receive support from employers and sponsors. The following reflect Student Accounts billings for tuition to employers and sponsors, who presumably provide stipends to students by private arrangements.				
US Army and Related Programs	138		+27	
US Navy and Related Programs	172		-3	
Foreign Countries and International Programs	203		-22	
Industry and Foundation	108		-6	
SUBTOTAL	621	16%	-4	-1%
SUMMARY BY SOURCES - FULL AWARDS				
<hr/>				
Total Regular Graduate Students: 3,774				
Federal Fellowships and Traineeships	336	9%	-51	-2%
Graduate Student Staff	1,750	46%	-54	-4%
Industrial and Foundation Awards	131	4%	+19	+1%
M. I. T. Endowed and Budgeted Funds	220	6%	+12	---
Students Sponsored by External Sources	621	16%	-4	-1%
TOTAL AWARDS	3,058	81%	-78	-6%

Medical Department

This report will present only the highlights of a very eventful year; a more detailed presentation will be published separately.

The past year saw the announcement of a new facility for the Medical Department, the selection of a new Medical Director, the first steps toward the development of teams of professionals to provide care to patients, the crystallization of a rationale for a program of health surveys, the development of auditable protocols for nurse-practitioners and physician's assistants, and a redefinition of the range of services available in-house at the Lincoln Laboratory. The Department was increasingly involved in the scientific, social, and political issues surrounding biohazards, developed a new program to aid employees who are experiencing difficulties at work because of personal problems, reformulated the structure of Institute committees relating to environmental safety and health, began construction of a new animal facility and remodeling of others, and -- for the first time in more than a decade -- saw a decrease in the number of patient visits to the Department.

The need of this Department for more and better space has been detailed in these reports many times. The exciting solution to space related problems appeared with the announcement of the funding of a new Health Center at M. I. T. to include accommodations both for the Division of Health Sciences and Technology, and for the Institute's health services, the Medical Department. Our eager anticipation of the new building is tempered by the necessity of obtaining a Certificate of Need, and we are now engaged in the careful planning and preparation necessary to that task. The Long Range Planning Committee, suggested in the report of the Visiting Committee, has been appointed by the President and is actively engaged in addressing the problems of programming and the determination of need process for the new facility.

The total number of visits to the Medical Department for the 12-month period from May 1976 through April 1977 was 115,325, this being 1,364 fewer than during the preceding 12 months, a decrease of about 1 percent. Within this overall decrease, however, there were increments in visits to the specialty clinics (allergy, dermatology, gynecology, neurology, nutrition, ophthalmology, orthopedics) and to the Dental Service.

There are several factors involved in this decrease. This past winter, contrary to expectations, was marked by a strikingly low incidence of respiratory infections. Our experience is shared not only by other college and university communities but by general hospitals and physicians in practice. It was, in fact, medically a rather quiet winter season.

In addition, we conducted far fewer health surveys this past year, (4,100 as opposed to 5,200 in 1975-76), enjoying, with our patients' forbearance, a moratorium while we developed a new program for health surveys and screens which we hope to initiate in fall, 1977. This diminished activity is also reflected in the decrement in X rays, electrocardiograms, and laboratory tests performed.

Further, with two full-time surgeons we are able to increase the efficiency of the surgical clinics and provide better continuity of care with fewer surgical visits.

Utilization of the Department's services by Health Plan members continues to increase as Health Plan membership increases. This past year, Health Plan members made

Medical Department

32 percent of all visits to our clinics, compared with 26 percent during the preceding year. The increment in number of visits by Health Plan members indicates that new members are using the Department at the same average level as their predecessors have been, that is at about six visits per member per year.

Students continue to make about the same proportion of total visits as formerly (about 40 percent) and the same is true of their spouses and dependents (about 5.5 percent). The apparent decrease in number of visits by employees who are not Health Plan members must be interpreted with caution, however, since employees who are Health Plan members are counted in the Health Plan category. It appears likely, then, that the reduction in total visits to the Department represents diminished utilization by all patient categories, and a reasonable expectation is that this will prove to be a temporary phenomenon.

Changes in Methods

Lincoln Laboratory. The incorporation of nurse-practitioners and physician's assistants into the operation of the health facility at the Lincoln Laboratory has resulted in a substantial widening of the range of services available to our patients there. The health professionals involved spend half of their time at the Laboratory and the remainder at the main Medical Department, strengthening the bridge between the two and facilitating the back-up function of the Department.

Protocols and Checklists. Nurse-practitioners and physician's assistants function best in close association with physicians. Our desire to maintain a low-barrier system, wherein patients may be seen quickly (almost always the same day that an appointment is requested) necessitates, however, a primary care or "walk-in" clinic staffed by non-physicians. In an effort to provide a substitute for physician leadership, standardize the level of care, and still allow initiative and professional judgment to be exercised, a group of protocols has been developed with the help of Dr. Anthony Komaroff and his colleagues at the Beth Israel Hospital and the Harvard School of Public Health. These protocols address the clinical presentation of the great majority of diseases seen. Checklists derived from the protocols make possible the rapid auditing of large numbers of clinic visits with identification of departures from the protocols. Our experience with this mode of practice is still very limited, and evaluation is being carried out.

Teams. The experience of others has indicated that a team of health professionals including physicians and non-physicians may have much to offer in addressing the complex problems and issues experienced by patients. The a priori expectation is that there should also be increased efficiency, better continuity of care, and better opportunity to understand the totality of the patient. We have, this past year, started toward the development of teams in the setting of Internal Medicine. Three groups have been identified with differing components, and the slow evolutionary process has been started.

Health Surveys. There has been, for some time, a malaise among physicians about the increasing importance given by many patients to the periodic "check-up" or health survey. In addition to some justifiable skepticism as to the value of the procedure, there is concern at the tendency of many patients to delay in consulting their doctors until the scheduled survey, to "save-up" symptoms. If ours is in reality the low-barrier system we hope it is, patients do not need to use the health survey as a means of gaining access to health care, and we can assume that the check-up is for the patient who feels well and has no reason to suspect he or she is not.

A schedule comprising annual screening examinations and less frequent physician administered health surveys has been devised, based upon this assumption and shaped according to age, sex, and known risk factors. Implementation of this schedule will enable us to offer appropriate

health surveillance to all members of the M.I.T. community who wish to accept it. Modifications of the basic screen will, in addition, make it easier for us to accommodate the special needs of those working in potentially hazardous environments. We hope to introduce this new system in the fall, recognizing the great importance of persuading our patients of the rationality of our approach.

Nurse-Practitioner Specialists. The Department has for several years had the advantage of two nurse-specialists, Marcia West, pediatric nurse practitioner and Helena McDonough, gynecologic nurse-midwife. This past year we have initiated a new service in this mode, with the appointment of Kathy Mulligan as dermatology nurse-practitioner. The value of these skillful people has been amply demonstrated and we plan to continue to explore the use of nurse-practitioner and physician-assistant specialists.

Personnel

The following is a list of appointments, promotions, and resignations of the staff of the Medical Department during the past year. It is gratifying to note that in the last two years, several physicians have left this Department to assume professorships at other institutions. One of these deserves special note: Dr. Warren Point had been a member of this Department for 10 years, during which time he had convincingly demonstrated his superb skills as a physician. That he left the Department to return to his native state and to play a central role there in medical education and health care is but small consolation to us.

The following appointments were made this year in the Department: Alan Bennett, M.D., Urologist; Paul Black, M.S., Assistant Radiation Protection Officer; Deborah Brandchaft, M.D., Postdoctoral Fellow, Psychiatry Service; Ann Marie Briley, M.D., Postdoctoral Fellow, Psychiatry Service; Gilbert R. Cherrick, M.D., Physician; Peggy Lee Coulter, R.N., Supervisor of Nurses, Outpatient Clinic; Florence Dingle, R.N., Nurse Coordinator, Obstetrics/Gynecology; Richard Doff, D.M.D., Dentist; Lois Eichler, Ph.D., Psychologist; Judith Klayman, M.S., Health Planner; Daniel Liberman, Ph.D., Microbiologist; Steven Locke, M.D., Postdoctoral Fellow, Psychiatry Service; Howard Ramseur, Ph.D., Postdoctoral Fellow, Psychiatry Service; George Reservitz, M.D., Urologist; David Rosenfield, M.D., Neurologist; Moshe Shalev, D.V.M., Clinical Veterinarian; Michael Shortsleeve, M.D., Radiologist; Shailini Singh, M.D., Obstetrician/Gynecologist; Robert Watton, D.M.D., Dentist; and Elizabeth Welch, R.N., Supervisor of Nurses, Off Hours Clinic.

Promotions this year included: Anthony Cavallerano, O.D., Senior Optometrist; Michael A. Kane, M.D., Assistant Medical Director; and Warren Point, M.D., Associate Medical Director.

The following resigned from the Medical Department staff: Leo D. Caplice, A.B.*, Administrative Officer; John Fromer, M.D.*, Dermatologist; Milton Helman, M.D., Dermatologist; Marguerite Heywood, M.D., Assistant Coordinator, Health Information and Education; Elmer Hinton, M.D.*, Physician; Karen C. Holmes, M.C.D., Coordinator, Health Information and Education; Elizabeth Hormann, M.D., Assistant Coordinator, Health Information and Education; Gail Magenis, M.S., Assistant Radiation Protection Officer; Joseph Perkell, D.M.D., Dentist; Warren Point, M.D., Associate Medical Director, Physician; David Rosenfield, M.D., Neurologist; John Stanbury, M.D., Endocrinologist; T. Phillip Sullivan, D.M.D., Dentist; Sherry Turkle, M.D., Postdoctoral Fellow, Psychiatry Service; Olga Wermer, M.D.*, Psychiatrist; Phillip Wickins, B.A., Manager, Medical Information Support Service; and Paul Winig, M.D., Obstetrician/Gynecologist.

*Retirement

Medical Department

Dental Service

Utilization of the Dental Service continued to increase this past year, with about 12,000 visits. The professionals working there are enduring less than optimal conditions, with limited space and a large patient population to be served. We are currently engaged in reassessing the goals and functions of the Service, particularly with the prospect of a new building.

Psychiatric Service

Dr. Merton J. Kahne has characterized the past year as being marked by a "studied blandness, beneath which there remained a good deal of social strain and emotional distress among all segments of the campus community." The number of patients and visits both increased slightly over the preceding year. Special projects included the initiation of a workshop on issues for the children of divorced or re-married parents under the leadership of Dr. Lora Tessman, the formulation of a special assistance program for troubled employees under the leadership of Dr. Alfred Koumans, further growth in activities and services by the Wives' Group led by Dr. Charlotte Green Schwartz in conjunction with Myra Rodrigues of the Social Work Service, and the beginning of concerted efforts to develop close liaison with other services within the Medical Department. A system also was developed to permit more rapid and effective collection of statistical data concerning M.I. T. Health Plan patients in outside therapy while preserving privacy.

Special note should be taken of the continued effectiveness of the use of the Infirmary for the care of some psychiatric patients. In this setting, many patients are able to receive treatment while maintaining some function in work or study, and avoiding the often prolonged hospitalization in psychiatric hospitals. There were 55 patients hospitalized at the Infirmary, using 437 patient days, an average of 7.95 days per patient. In contrast, 27 patients were hospitalized at other hospitals, using 1,596 patient days, an average of 59 days per patient.

Social Work Service

Visits to the Social Work Service increased slightly this past year (1,376/1,311), and most strikingly the number of Health Plan member visits doubled (423/211). Ms. Rodrigues continues to be very active with minority staff and student affairs, as well as with the group to develop a new assistance program for employees. She and Jacqueline A. Buck, Chief Social Worker, have been working with the President's Privacy Committee and the Task Force for the Handicapped, and continue to be involved with the activities of the Technology Children's Center.

Surgical Service

With the advantage of two full-time surgeons to increase efficiency and continuity of care, it was possible to decrease surgical clinic time from 57 to 40 hours per week. Although surgical admissions to the Infirmary decreased by 30 percent, there was an increase in the number of surgical patients treated in the Off Hours Clinic and in the brief-stay Observation Unit (4 percent).

Athletic injuries increased slightly in number. This year baseball (71) displaced soccer (65) from the top three sports producing injuries, while basketball (104) and football (87) maintained their unenviable positions. Bicycle accidents followed with 50 and ice hockey with 42.

Obstetrical and Gynecological Service

This has been a busy year, with 90 deliveries among Health Plan members and increasing use of the clinic by the community. We were very fortunate to persuade Dr. Shailini Singh to join the Department as full-time Obstetrician/Gynecologist. The ratio of 71 births per 1,000 member-families which we experienced contrasts with the 37/1,000 experience of non-Health Plan employees and, we feel, demonstrates not only the fecundity of our patients and their confidence in our service but also the generosity of the maternity benefits available to Health Plan members.

We are increasingly aware of the desire of many of our obstetric patients to explore methods of delivery which may differ from the conventional. Our practice has been to accommodate as many of these alternative methods as is consistent with safety for mother and child, and good sense. With the passage of legislation permitting a nurse-midwife to preside at delivery under carefully defined circumstances, we will continue to explore with our patients possible and sensible alterations of style.

Environmental Medical Service (E.M.S.)

The appointment of Dr. Daniel Liberman to the staff of E.M.S. in March of this year illustrates the importance of the increasing activity of the Institute and this Department in the area of biological hazards. Dr. Melvin H. Chalfen, with Richard Chamberlin and, later, Dr. Liberman, has been centrally involved in the political controversy around the issues of recombinant DNA technology at local, state, and national levels. Dr. Liberman heads a new office at E.M.S., the Biohazards Assessment Office. His work, in connection with the Committee on Assessment of Biohazards, will include the creation of a registry of biological agents used at the Institute and an assessment of their hazards. He also has been able to provide some leadership in similar programs at sister institutions.

The formation of a Biology Safety Administrative Group to review health and safety policies in the area of biology stimulated a restructuring of Institute committees relating to environmental safety and health.

The solid and steady work of the Radiation Protection Office and the Industrial Hygiene Office continues. The number of registered radiation workers, radioisotope laboratories, and monitoring and testing activities has increased. The Bates Linear Accelerator Radiation Protection Office, now a separate unit, required additional personnel as the operating schedules of the Accelerator have moved to 14 and 21 day periods of 24-hour operation.

Division of Laboratory Animal Medicine (D.L.A.M.)

The commitment of the Institute to renovation of existing animal facilities and the construction of a centralized animal care facility begins to approach realization with the construction of the new Interim Animal Care Facility on Vassar Street. Renovations have also begun, aided by a National Institutes of Health Animal Resource Improvement grant. A major impetus to this essential work has been derived from the approval and funding by the National Cancer Institute of the M.I.T. Animal Facilities Renovation proposal.

The M.I.T. Animal Research Diagnostic Laboratory has completed its first full year of operation and is demonstrating its value as a focal resource to elucidate and diagnose problems in laboratory animals housed at M.I.T. The staff of the Laboratory has been augmented this past year to include a histologist and microbiologist, Celia Galus. Certification in the specialty of microbiology has been granted to the Laboratory by the Massachusetts Department of Public Health.

Dr. Moshe Shalev, a veterinarian with both clinical and research interests, has joined the Division, and is already heavily involved in its activities. During the coming year he will concentrate on developing diagnostic capabilities in clinical chemistry and immunology, as well as joining Dr. Paul Newberne, Professor of Nutrition, in the genetic screening of newly developed hamster lines.

An environmental survey program has been established to monitor each of the animal care facilities as to level and type of bacterial contamination. Typing of K. pneumoniae, an organism responsible for many diseases in animals, is being done as a method of studying those diseases; S. aureus is also being studied to determine whether there is any correlation between antibiotic susceptibility patterns and bacteriophage types. The ability of organisms resistant to many antibiotics to transfer this resistance to sensitive organisms is being studied. Serological survey of the rodent colonies at M.I.T. is continuing, providing vital information in the program of monitoring disease in the many strains of mice from differing sources which are housed at the M.I.T. Cancer Research Center. Direct participation in the detection of disease in humans also occurred this past year when the D.L.A.M. was asked to identify an organism suspected of causing illness in two patients. The organism (a *Leptospira*) was successfully identified by darkfield examination of serum from both patients and was successfully cultured in one.

Research activities within the Division also have resulted in the preparation of 24 papers for presentation at scientific meetings and/or publication. Teaching activities included the creation of a file of kodachrome slides for teaching purposes, a course called Laboratory Animals: Usage in Biological Experimentation for undergraduate and graduate students, participation in the Comparative Pathology Seminar, the undertaking of summer internship programs for veterinary students, and participation in training programs for technicians and investigators. Professional and technical staff are scheduled to participate in the annual training program of the national American Association for Laboratory Animal Services for animal care technicians.

Health Information and Education

Under the direction of Constance Bean and Elizabeth Hormann, several programs were continued. These included weight control, cessation of smoking, prenatal and parent education, the Health Plan Newsletter, revision of the M.I.T. sex education booklet, and Patient Advocacy. There were in addition several new programs, including expansion of the pregnancy and parenting library; a group to consider the issues for children of single, divorced, or re-married parents conducted by Dr. Tessman; and an exploratory program to help prepare patients for hospital experiences. All of the programs are designed to supplement the kinds of preventive health information normally offered in physician and nurse office visits.

The Patient Advocacy program encourages patients to call, write, or visit the Health Information Office to resolve problems. By learning what the patients' perspectives are, the Medical Department can revise its procedures where necessary and help patients to use its services more effectively.

M.I.T. Health Plan

Growth of the Plan continued, with an increase to 5,712 members from the 4,865 level of a year ago. Increased utilization of the Department's services by Health Plan members continues to be proportionate to the increase in membership. The forecasts of costs for the past year have been achieved and the Plan revenues allocated to the purchase of departmental services continue to be an important source of support for the Department.

Vice President and Dean of the Graduate School

Because of actual and projected continuation of growth in membership and other factors, it will be possible during this coming year to erase for most of the M.I. T. community, the difference in cost between the M.I. T. Health Plan and the Master Medical Blue Cross-Blue Shield policy offered by the Insitiute.

MELVIN H. RODMAN M. D.

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	1904-05	1,561	1943-44	1,579
1866-67	137	1905-06	1,466	1944-45	1,198
1867-68	167	1906-07	1,397	1945-46	1,538
1868-69	172	1907-08	1,415	1946-47	5,172
1869-70	206	1908-09	1,461	1947-48	5,662
1870-71	224	1909-10	1,479	1948-49	5,433
1871-72	261	1910-11	1,506	1949-50	5,458
1872-73	348	1911-12	1,559	1950-51	5,171
1873-74	276	1912-13	1,611	1951-52	4,874
1874-75	248	1913-14	1,685	1952-53	5,074
1875-76	255	1914-15	1,816	1953-54	5,183
1876-77	215	1915-16	1,900	1954-55	5,348
1877-78	194	1916-17	1,957	1955-56	5,648
1878-79	188	1917-18	1,698	1956-57	6,000
1879-80	203	1918-19	1,819	1957-58	6,179
1880-81	253	1919-20	3,078	1958-59	6,259
1881-82	302	1920-21	3,436	1959-60	6,270
1882-83	368	1921-22	3,505	1960-61	6,289
1883-84	443	1922-23	3,180	1961-62	6,454
1884-85	579	1923-24	2,949	1962-63	6,695
1885-86	609	1924-25	2,938	1963-64	6,925
1886-87	637	1925-26	2,813	1964-65	7,151
1887-88	720	1926-27	2,671	1965-66	7,408
1888-89	827	1927-28	2,712	1966-67	7,567
1889-90	909	1928-29	2,868	1967-68	7,730
1890-91	937	1929-30	3,066	1968-69	7,764
1891-92	1,011	1930-31	3,209	1969-70	8,024
1892-93	1,060	1931-32	3,188	1970-71	7,799
1893-94	1,157	1932-33	2,831	1971-72	7,717
1894-95	1,183	1933-34	2,606	1972-73	7,850
1895-96	1,187	1934-35	2,507	1973-74	7,888
1896-97	1,198	1935-36	2,540	1974-75	8,050
1897-98	1,198	1936-37	2,793	1975-76	8,482
1898-99	1,171	1937-38	2,966	1976-77	8,597
1899-00	1,178	1938-39	3,093		
1900-01	1,277	1939-40	3,100		
1901-02	1,415	1940-41	3,138		
1902-03	1,608	1941-42	3,055		
1903-04	1,528	1942-43	3,048		

*From 1943 to 1946 Army and Navy students are omitted (see Table III-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	-	1965	2,090	1,568
1949	1,875	171	1966	2,054	1,787
1950	1,852	259	1967	2,218	1,829
1951	1,861	813	1968	2,490	1,739
1952	1,689	832	1969	2,241	1,719
1953	1,672	1,289	1970	2,185	1,666
1954	1,675	1,398	1971	2,197	1,109
1955	1,619	1,653	1972	2,121	1,235
1956	1,553	2,497	1973	2,205	1,367
1957	1,548	1,757	1974	2,153	1,701
1958	1,650	1,752	1975	2,238	1,430
1959	1,635	1,510	1976	2,317	1,614
1960	1,600	1,696			
1961	1,668	1,412			
1962	1,748	1,763			
1963	1,808	1,397			
1964	1,882	1,492			

*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 Academic Staff Count

	Professors	Administration also Professors	Institute Professors	Emeriti-Part Time	Adjunct Professors	Associate Professors	Assistant Professors	Sr. Lecturers & Professors Emeriti	Sr. Lecturers	Lecturers	Sr. Research Scientists	Instructors	Technical Instructors	Research Associates	Technical Assistants	Research Assistants	Teaching Assistants	Instructor	Grad	Total	Visiting Professors	Others ¹
Institute Professors	10	-	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13	2	1
School of Architecture and Planning																						
Architecture	15	1	-	1	12	12	1	-	7	1	-	2	5	7	-	11	21	-	-	95	2	3
Urban Studies and Planning	9	2	-	1	16	8	-	-	6	6	-	-	-	1	-	15	-	5	-	63	3	10
Total	24	3	-	2	28	20	1	-	14	14	-	2	5	8	-	26	21	5	-	159	5	14
School of Engineering																						
Aeronautics and Astronautics	21	3	-	1	4	4	2	1	13	13	-	-	2	11	-	104	2	-	-	168	1	1
Chemical Engineering	10	2	-	-	3	9	1	1	5	3	-	1	2	10	-	51	19	1	1	115	1	7
Civil Engineering	21	1	-	-	11	16	-	3	3	3	-	-	-	7	-	97	15	-	-	174	-	8
Electrical Engineering and Computer Science	50	8	-	1	19	19	3	-	19	19	-	-	4	16	-	199	99	6	-	439	2	21
Materials Science and Engineering	21	2	-	1	4	6	-	-	-	-	-	-	4	17	-	104	16	-	-	175	-	10
Mechanical Engineering	25	3	-	1	12	9	1	6	14	14	-	-	3	7	1	132	7	4	-	225	1	18
Nuclear Engineering	15	1	-	-	4	4	-	-	1	1	-	-	-	4	-	48	23	1	-	101	1	6
Ocean Engineering	9	2	-	-	-	3	-	-	-	-	-	-	-	3	-	50	7	-	-	84	1	10
School Professors	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	1	-
Total	176	22	-	4	66	70	7	11	55	55	1	1	11	75	1	785	188	12	-	1,485	8	84
School of Humanities and Social Science																						
Educational Programs	4	-	-	-	2	3	1	-	-	-	-	-	-	2	3	-	-	-	-	15	2	7
Economics	11	2	-	-	4	3	2	-	-	-	-	-	-	-	-	3	25	-	-	50	1	6
Humanities	19	2	-	-	15	16	3	1	17	17	-	15	2	1	11	-	-	-	-	102	3	3
Linguistics and Philosophy	10	1	-	-	3	6	-	-	-	-	-	-	-	1	-	23	9	-	-	53	-	3
Political Science	12	3	-	-	5	4	-	2	1	1	-	-	-	-	-	4	15	1	-	47	1	1
Psychology	6	1	-	-	3	1	-	-	-	-	-	1	2	14	-	2	1	-	-	31	-	14
Total	62	9	-	-	32	33	6	3	18	18	-	16	4	18	14	32	50	1	-	298	7	34
Alfred P. Sloan School of Management																						
Management	25	3	-	2	12	20	1	8	2	2	-	1	-	7	2	30	34	1	-	148	6	13

Table III Classification of Students since 1974

Course	1974-75				1975-76				1976-77				Course Number			
	2	3	4	G Total	2	3	4	G Total	2	3	4	G Total				
School of Architecture and Planning																
Architecture, IV	53	46	45	163	307	37	53	54	184	328	38	46	50	201	335	IV
Architecture, IV-B	1	-	2	-	3	1	1	1	-	3	2	2	2	-	6	IV-B
Urban Studies and Planning, XI	9	20	25	140	194	5	10	33	127	175	10	12	18	127	167	XI
Total	63	66	72	303	504	43	64	88	311	506	50	60	70	328	508	Total
School of Engineering																
Aeronautics and Astronautics, XVI	18	12	21	155	206	26	17	13	191	247	46	28	15	178	267	XVI
Aeronautics and Astronautics, XVI-B (Cooperative)	1	4	1	-	6	-	4	3	-	7	2	2	3	-	7	XVI-B
Chemical Engineering, X	44	37	31	149	261	78	57	40	163	338	99	96	44	181	420	X
Chemical Engineering, X-C	3	2	7	-	12	1	3	5	-	9	3	1	7	-	11	X-C
Civil Engineering, I	23	52	54	264	393	41	49	58	258	406	52	67	57	218	394	I
Electrical Engineering and Computer Science, VI	105	132	112	489	1125	160	115	134	484	1147	203	141	127	496	1223	VI
Program 1-Electrical Science and Engineering	70	89	128	-	-	79	61	114	-	-	76	93	87	-	-	-
Program 3-Computer Science and Engineering	1	57	43	27	128	3	32	58	37	130	-	66	48	55	169	VI-A
Electrical Engineering and Computer Science, VI-A (Cooperative)	8	21	12	138	179	13	9	21	143	186	16	7	8	160	191	III
Materials Science and Engineering, III	-	-	1	-	1	1	-	-	-	1	2	-	1	-	3	III-A
Materials Science and Engineering, III-B (Cooperative)	-	-	-	-	-	1	2	1	-	4	3	10	2	-	15	III-B
Mechanical Engineering, II	57	67	43	231	398	56	66	66	216	404	105	77	74	227	483	II
Mechanical Engineering, II-A	3	8	10	-	21	7	14	6	-	27	15	12	16	-	43	II-A
Mechanical Engineering, II-B (Cooperative)	-	7	4	-	11	4	4	7	-	15	5	5	7	-	17	II-B
Mechanical Engineering, II-T-Textile Technology	-	-	-	4	4	-	-	-	5	5	-	-	-	2	2	II-T
Nuclear Engineering, XXII	11	15	10	97	133	17	3	-	184	204	13	19	2	190	224	XXII
Ocean Engineering, XIII	-	-	2	-	6	10	9	12	100	131	17	10	10	97	134	XIII
Ocean Engineering, XIII-C (Cooperative)	-	4	2	-	6	1	2	1	-	4	-	-	2	-	2	XIII-C
Ocean Engineering, XIII-W (Woods Hole)	-	-	-	12	12	-	-	-	10	10	-	-	-	11	11	XIII-W
Naval Construction and Engineering, XIII-A	-	-	-	63	63	-	-	-	68	68	-	-	-	62	62	XIII-A
Shipping and Shipbuilding Management, XIII-B	-	-	-	7	7	-	-	-	6	6	-	-	-	3	3	XIII-B
Center for Advanced Engineering Study, EN	-	-	-	66	66	-	-	-	82	82	-	-	-	42	42	EN
Total	344	507	479	1846	3176	498	447	539	1947	3431	657	634	510	1922	3723	Total

School of Humanities and Social Science

Economics,XIV	21	17	26	118	182	14	27	22	116	179	8	27	33	122	190	XIV
Humanities and Engineering,XXI-A	1	1	2	-	4	-	1	4	-	5	-	7	3	-	10	XXI-A
Humanities and Science,XXI-B	3	15	21	-	39	6	9	25	-	40	4	8	12	-	24	XXI-B
Linguistics and Philosophy,XXIV	-	1	-	59	60	3	-	2	51	56	2	7	-	54	63	XXIV
Political Science,XXVII	2	8	5	102	117	7	4	9	90	110	7	9	10	101	127	XXVII
Psychology,IX	-	-	-	30	30	-	-	-	29	29	-	-	-	29	29	IX
Total	27	42	54	309	432	30	41	62	286	419	21	58	58	306	443	Total

Alfred P. Sloan School of Management

Management,XV	25	35	55	384	499	20	35	52	305	412	21	45	40	347	453	XV
Management Fellows,XV-A	-	-	-	-	-	-	-	-	68	68	-	-	-	72	72	XV-A
Management-Operations Research,XV-B	-	-	-	-	-	-	-	-	15	15	-	-	-	14	14	XV-B
Total	25	35	55	384	499	20	35	52	388	495	21	45	40	433	539	Total

School of Science

Biology,VII	56	91	99	139	385	57	58	81	132	328	53	72	61	135	321	VII
Biology,VII-A	4	8	13	-	25	8	8	20	-	36	7	13	9	-	29	VII-A
Biology,VII-B	23	26	19	-	68	30	45	26	-	101	10	44	44	-	98	VII-B
Biology,VII-W(Woods Hole)	-	-	-	14	14	-	-	-	14	14	-	-	-	15	15	VII-W
Chemistry,V	58	61	50	170	339	64	52	56	171	343	59	53	43	177	332	V
Earth and Planetary Sciences,XII	17	28	25	89	159	18	21	29	81	149	16	25	23	83	147	XII
Earth and Planetary Sciences,XII-W(Woods Hole)	-	-	-	32	32	-	-	-	38	38	-	-	-	39	39	XII-W
Interdisciplinary Science Program,XXV	3	4	10	-	17	2	6	7	12	27	2	7	7	16	32	XXV
Mathematics,XVIII	53	77	90	125	345	65	68	86	138	357	47	68	78	127	320	XVIII
Meteorology,XIX	-	-	-	40	40	-	-	-	51	51	-	-	-	51	51	XIX
Meteorology,XIX-W(Woods Hole)	-	-	-	14	14	-	-	-	12	12	-	-	-	12	12	XIX-W
Nutrition and Food Science,XX	-	-	-	153	153	-	-	-	172	172	-	-	-	188	188	XX
Physics,VIII	91	111	93	253	548	89	95	122	253	559	103	88	101	255	547	VIII
Health Sciences and Technology,HST	-	-	-	43	43	-	-	-	43	43	-	-	-	42	42	HST
Total	305	406	399	1072	2182	333	353	427	1117	2230	297	370	366	1140	2173	Total

Undesignated	216				216	232				232	158			158		Undes.
--------------	-----	--	--	--	-----	-----	--	--	--	-----	-----	--	--	-----	--	--------

First Year	1041			1041	1169	1169			1169	1053	1053			1053		First Year
------------	------	--	--	------	------	------	--	--	------	------	------	--	--	------	--	------------

Grand Total	1041	980 ¹	1056 ¹	1059 ¹	3914	8050	1169	1156	940 ²	1168 ²	4049	8482	1053	1204 ³	1167 ³	1044 ³	4129	8597	Grand Total
-------------	------	------------------	-------------------	-------------------	------	------	------	------	------------------	-------------------	------	------	------	-------------------	-------------------	-------------------	------	------	-------------

(not included in above figures)

Non-Institute Students from Harvard	3	2	9	168	182	1	1	2	209	213	5	2	15	251	272	NIH
Non-Institute Students from Wellesley	44	77	106	3	230	59	60	119	2	240	4	63	76	84	-	NIW

¹These totals include 1 student in second year, 5 in third year and 2 in fourth year on Foreign Study; 2 students in third year on Domestic Study
²These totals include 3 students in third year, 1 student in fourth year on Foreign Study; 3 students in third year, 1 in fourth year on Domestic Study
³These totals include 7 students in third year, 3 in fourth year on Foreign Study; 1 student in second year, 2 students in third year on Domestic Study

Table III-A Women Students by Schools, Courses and Years, 1976-77¹

Course	2	3	4	Graduate		Total	
				Regular	Special		
SCHOOL OF ARCHITECTURE AND PLANNING							
Architecture,IV	10	11	10	56	6	93	
Architecture,IV-B	-	1	-	-	-	1	
Urban Studies and Planning,XI	3	8	3	43	14	71	
Total	13	20	13	99	20	165	
SCHOOL OF ENGINEERING							
Aeronautics and Astronautics,XVI	2	3	2	6	3	16	
Chemical Engineering,X	21	23	10	22	-	76	
Chemical Engineering,X-C	2	-	2	-	-	4	
Civil Engineering,I	12	21	6	15	3	57	
Electrical Engineering and Computer Science,VI							
Program 1-Electrical Science and Engineering	13	6	4				
Program 3-Computer Science and Engineering	2	5	5	21	6	62	
Electrical Engineering and Computer Science,VI-A (Cooperative)							
Program 1-Electric Science and Engineering	-	3	2	5	-	13	
Program 3-Computer Science and Engineering	-	2	1				
Materials Science and Engineering,III	6	3	1	20	-	30	
Materials Science and Engineering,III-A	1	-	1	-	-	2	
Materials Science and Engineering,III-B(Cooperative)	-	6	2	-	-	8	
Mechanical Engineering,II	12	13	4	11	1	41	
Mechanical Engineering,II-A	5	-	4	-	-	9	
Mechanical Engineering,II-B(Cooperative)	-	2	1	-	-	3	
Ocean Engineering,XIII	4	1	-	3	-	8	
Ocean Engineering,XIII-C(Cooperative)	-	-	1	-	-	1	
Ocean Engineering,XIII-W(Woods Hole)	-	-	-	1	-	1	
Nuclear Engineering,XXII	2	1	1	6	1	11	
Center for Advanced Engineering Study,EN	-	-	-	-	1	1	
Total	82	89	47	110	15	343	
SCHOOL OF HUMANITIES AND SOCIAL SCIENCE							
Economics,XIV	2	7	2	16	3	30	
Humanities and Engineering,XXI-A	-	2	1	-	-	3	
Humanities and Science,XXI-B	2	1	4	-	-	7	
Linguistics and Philosophy,XXIV	1	1	-	20	1	23	
Political Science,XVII	1	2	1	23	2	29	
Psychology,IX	-	-	-	10	-	10	
Total	6	13	8	69	6	102	
ALFRED P. SLOAN SCHOOL OF MANAGEMENT							
Management,XV	3	12	2	72	9	98	
Management Fellows,XV-A	-	-	-	4	2	6	
Management-Operations Research,XV-B	-	-	-	3	-	3	
Total	3	12	2	79	11	107	
SCHOOL OF SCIENCE							
Biology,VII	13	22	20	36	9	100	
Biology,VII-A	2	3	5	-	-	10	
Biology,VII-B	7	21	15	-	-	43	
Biology,VII-W(Woods Hole)	-	-	-	4	-	4	
Chemistry,V	12	9	7	28	2	58	
Earth and Planetary Sciences,XII	8	11	5	15	-	39	
Earth and Planetary Sciences,XII-W(Woods Hole)	-	-	-	8	-	8	
Interdisciplinary Science Program,XXV	1	4	-	5	-	10	
Mathematics,XVIII	8	13	16	13	-	50	
Meteorology,XIX	-	-	-	5	1	6	
Nutrition and Food Science,XX	-	-	-	52	6	58	
Physics,VIII	7	12	3	23	1	46	
Health Sciences and Technology,HST	-	-	-	-	7	7	
Total	58	95	71	189	26	439	
Undesignated		32				32	
First Year	173					173	
Grand Total	173	194	229	141	546	78	1361

¹Also included in Table III

Total undergraduate women 737, 20 of whom are specials.

Table III-B Special Students by Schools,Courses and Years,1976-77¹

Course	Year				Total
	2	3	4	6	
School of Architecture and Planning					
Architecture,IV	1	3	1	12	17
Urban Studies and Planning,XI	1	2	-	28	31
Total	2	5	1	40	48
School of Engineering					
Aeronautics and Astronautics,XVI	-	1	-	24	48
Chemical Engineering,X	-	1	-	2	3
Civil Engineering,I	-	2	-	16	18
Electrical Engineering and Computer Science,VI, VI-1,VI-3,VI-A	1	2	1	44	48
Materials Science and Engineering,III	-	-	-	6	6
Mechanical Engineering,II	1	-	-	9	10
Ocean Engineering,XIII	-	-	-	3	3
Nuclear Engineering,XXII	1	-	-	2	3
Center for Advanced Engineering Study,EN	-	-	-	42	42
Total	3	6	1	148	148
School of Humanities and Social Science					
Economics,XIV	1	1	-	6	8
Humanities and Science,XXI-B	2	-	1	-	3
Linguistics and Philosophy,XXIV	1	1	-	2	4
Political Science,XVII	-	-	-	12	12
Psychology,IX	-	-	-	1	1
Total	4	2	1	21	28
Alfred P. Sloan School of Management					
Management,XV,XV-A	-	-	1	37	38
School of Science					
Biology,VII,VII-A,VII-B	1	3	4	19	27
Chemistry,V	1	-	1	2	4
Interdisciplinary Science Program,XXV	-	-	-	4	4
Mathematics,XVIII	-	-	1	10	11
Meteorology,XIX	-	-	-	2	2
Nutrition and Food Science,XX	-	-	-	18	18
Physics,VIII	1	3	1	12	17
Health Sciences and Technology,HST	-	-	-	42	42
Total	3	6	7	109	125
Undesignated	4				4
Grand Total	16	19	11	355	401

¹Included also in Table III

Table IV Continued, Former, and New Students

	1972-73	1973-74	1974-75	1975-76	1976-77
Continued Students					
Undergraduate and graduate students registered at the end of the last academic year (including special students)	5,337	5,426	5,513	5,747	5,980
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)	273	306	249	227	272
Undergraduate students who enrolled for the first time since secondary school (excluding special students)	1,041	893	1,033	1,156	1,042
Undergraduate students who enrolled for the first time at the Institute and who transferred from another collegiate institution (excluding special students)	104	85	99	130	134
Graduate students who enrolled for the first time at the Institute (excluding special students)	883	884	849	935	958
Special undergraduate and graduate students with no previous Institute registration	212	294	307	287	211
Total	7,850	7,888	8,050	8,482	8,597

Table V Regular Students from Other Colleges and Graduates of M.I.T.
Classified by Schools and Courses 1976-77

	Entered with no previous degree	Entered with Bachelor's degree from other colleges	Entered Graduate School with Bachelor's degree from M.I.T.
School of Architecture and Planning			
Architecture(IV,IV-B)	20	154	35
Urban Studies and Planning(XI)	3	91	8
Total	23	245	43
School of Engineering			
Aeronautics and Astronautics(XVI,XVI-B)	12	123	31
Chemical Engineering(X,X-C)	22	145	34
Civil Engineering(I)	23	170	32
Electrical Engineering and Computer Science (VI,VI-1,VI-3,VI-A)	101	303	204
Materials Science and Engineering(III, III-A,III-B)	3	120	34
Mechanical Engineering(II,II-A,II-B,II-T)	26	184	36
Nuclear Engineering(XXII)	5	167	21
Ocean Engineering(XIII,XIII-A,XIII-B, XIII-C,XIII-W)	3	157	13
Total	195	1369	405
School of Humanities and Social Science			
Economics(XIV)	9	108	8
Humanities and Engineering or Science (XXI-A,XXI-B)	4	-	-
Linguistics and Philosophy(XXIV)	-	47	5
Political Science(XVII)	-	82	7
Psychology(IX)	-	23	5
Total	13	260	25
Alfred P. Sloan School of Management			
Management(XV,XV-A,XV-B)	11	348	48
School of Science			
Biology(VII,VII-A,VII-B,VII-W)	25	115	16
Chemistry(V)	9	170	5
Earth and Planetary Sciences(XII,XII-W)	3	98	24
Interdisciplinary Science Program(XXV)	1	10	2
Mathematics(XVIII)	27	101	16
Meteorology(XIX,XIX-W)	-	57	4
Nutrition and Food Science(XX)	-	134	36
Physics(VIII)	28	174	69
Total	93	859	172
Undesignated	3		
First Year	1		
Grand Total	339	3081	693

Table VI List of Colleges and Universities with Number of Graduates
Entering the Institute as Regular Students¹

Alabama, University of, Huntsville	1	Goddard College	2
Albion College	2	Hamilton College	1
Alfred University	2	Hampshire College	2
Allegheny College	1	Harvard University	20
Amherst College	1	Harvey Mudd College	5
Antioch College	1	Haverford College	2
Arizona, University of	4	Holy Cross, College of the	2
Atlanta University Center	1	Hope College	1
Bard University	1	Houston, University of	2
Barnard College	3	Howard University	1
Boston College	2	Hunter College	1
Boston University	7	Idaho, University of	1
Bowling Green State University	1	Illinois, University of, Urbana-Champaign	10
Brandeis University	11	Illinois Benedictine College	1
Brigham Young University	3	Illinois Institute of Technology	1
Brown University	9	Indiana University, Bloomington	2
Bryn Mawr College	1	Iowa, University of	2
Bucknell University	3	Iowa State University of Science and Technology	2
California, University of, Berkeley	21	Johns Hopkins University	7
California, University of, Davis	2	Kansas, University of	4
California, University of, Irvine	3	Kansas State University	2
California, University of, Los Angeles	9	Kentucky, University of	1
California, University of, Riverside	1	Ladycliff College	1
California, University of, San Diego	2	Lafayette College	1
California, University of, Santa Barbara	1	Lamar University	1
California, University of, Santa Cruz	2	Lawrence University	1
California Institute of Technology	10	Lehigh University	2
California State University, Fullerton	1	Louisiana State University and Agricultural and Mechanical College	2
Carleton College (Mississippi)	1	Louisiana Technical University	1
Carnegie-Mellon University	3	Louisville, University of	2
Case Western Reserve University	2	Lowell, University of	1
Catholic University of America	1	Lowell Technological Institute	2
Chicago, University of	5	Macalester College	1
Cincinnati, University of	3	Manhattan College	1
Citadel, The	1	Marquette University	3
City College, The	5	Maryland, University of	5
Clarkson College of Technology	1	Massachusetts, University of, Amherst	8
Cleveland State University	1	Massachusetts, University of, Boston	3
Colby College	1	Massachusetts College of Art	1
Colgate University	1	Massachusetts Institute of Technology	254
Colorado, University of	5	Medical College of Pennsylvania	1
Colorado College	1	Miami, University of, Florida	2
Colorado State University	1	Miami, University (Ohio)	2
Columbia University	11	Michigan, University of, Ann Arbor	17
Connecticut, University of	6	Michigan State University	7
Connecticut College	1	Middlebury College	3
Cooper Union, The	3	Minnesota, University of	4
Cornell University	20	Missouri, University of, Columbia	2
Dartmouth College	5	Morris Brown College	1
Dawson College	1	Mount Holyoke College	5
Dayton, University of	2	Nebraska Wesleyan University	1
Denison University (Ohio)	1	Newark College of Engineering	3
DePaul University	1	New Hampshire, University of	2
Detroit, University of	2	New Jersey Institute of Technology	2
Drexel University	4	New Mexico State University	1
Duquesne University	1	New York City, University of, Brooklyn College	2
Earlham College	2	New York, State University of, Albany	4
Fairleigh Dickinson University	1	New York, State University of, Binghamton	1
Florida, University of	4	New York, State University of, Buffalo	6
Florida Atlantic University	2	New York, State University of, Stonybrook	9
Florida Institute of Technology	1	New York Medical College	1
Florida State University	1	New York University	7
Franklin Marshall College	1	Newton College of Sacred Heart	1
General Motors Institute	7	North Carolina, University of, Chapel Hill	3
George Washington University	1	North Carolina Agricultural and Technical State University	3
Georgetown University	1	North Carolina State University, Raleigh	1
Georgia, University of	2	Northeastern University	14
Georgia Institute of Technology	10		
Gettysburg College	1		

Northern Kansas State College	1	West Virginia, University of	1
Notre Dame, University of	6	Westchester Community College	1
Oakland University	1	Whitman College	2
Oberlin College	3	William and Mary, College of	1
Ohio State University	3	Williams College	1
Oklahoma, University of	1	Wisconsin, University of, Eau Claire	1
Oregon, University of	5	Wisconsin, University of, Green Bay	1
Oregon State University	2	Wisconsin, University of, Madison	12
Pennsylvania, University of	12	Wisconsin, University of, Milwaukee	1
Pennsylvania State University	6	Worcester Polytechnic Institute	2
Pittsburgh, University of	2	Xavier University	1
Polytechnic Institute of New York	1	Yale University	13
Pomona College	3		
Portland State College	1		961
Princeton University	20		
Purdue University	5		
Queen Mary College	1	Foreign	
Queens College (New York)	1	Al-Jami'ah Al-Amiriyah Fi Bayrut (Lebanon)	1
Radcliffe College	1	Alberta, University of (Canada)	1
Rensselaer Polytechnic Institute	6	Architectural Association School of Architecture (England)	1
Rhode Island, University of	2	Aristotelion Panepistimion Thessalonikis (Greece)	1
Rhode Island School of Design	4	Asia Institute of Technology (Thailand)	1
Rice University	3	Banaras Hindu University (India)	1
Ripon College	1	Bangladesh University of Engineering and Technology (Bangladesh)	1
Rochester, University of	4	Bombay Technical Institute (India)	1
Rose-Hulman Institute of Technology	1	Bristol, University of (England)	1
Rosemont College	1	Cairo University (United Arab Republic)	1
Rutgers, The State University	6	Calgary, University of, (Canada)	1
Saint Louis University	2	Cambridge University (England)	4
Saint Olaf College	1	Cape Town, University of (South Africa)	1
San Bernadino Valley College	1	Carleton University (Canada)	2
Simmons College	1	Chung Cheng Institute of Technology (Republic of China)	1
Smith College	3	College of Science (Republic of China)	1
Southeastern Massachusetts University	1	Dacca University (Bangladesh)	1
Southern California, University of	2	Daneshgah Pahlavi (Iran)	1
Southern Methodist University	2	Daneshgah Sanati Arya-Mehr (Iran)	10
Southern University and Agricultural and Mechanical College	1	Daneshgah Tehran (Iran)	3
Stanford University	13	Daneshkadeh Sanati (Iran)	5
Swarthmore College	4	Den Polytekniske Laereanstalt, Danmarks Tekniske Hojskole (Denmark)	1
Syracuse University	4	Ecole Centrale des Arts et Manufactures (France)	2
Temple University	2	Ecole Nationale d'Ingenieurs de Constructions Aeronautiques (France)	1
Tennessee, University of, Knoxville	2	Ecole Nationale des Ponts et Chaussees (France)	4
Tennessee State University	2	Ecole Nationale Polytechnique (Algeria)	1
Tennessee Technological University	2	Ecole Nationale Superieure d'Arts et Metiers (France)	2
Texas, University of, Austin	7	Ecole Nationale Superieure de Mines des Paris (France)	2
Texas A & M University	2	Ecole Nationale Superieure des Industries Chimiques (France)	1
Tri State College	1	Ecole Nationale Superieure des Menes le Saint-Etienne (France)	1
Trinity College (Connecticut)	1	Ecole Nationale Superieure des Telecommunica- tions (France)	1
Tufts University	16	Ecole Polytechnique Federale (Switzerland)	1
Tulsa, University of	2	Ecole Speciale des Travaux Aeronautiques (France)	1
Union College (New York)	2	Ecole Superieure d'Electricite (France)	1
U. S. Air Force Academy	3	Eidgenossische Technische Hochschule Zurich (Switzerland)	2
U. S. Coast Guard Academy	3	Escola Naval (Portugal)	2
U. S. Merchant Marine Academy	1	Escuela Ingenieria Naval (Chile)	1
U. S. Military Academy	4	Escuela Tecnica Superior de Ingenieros Aeronauticos (Spain)	1
U. S. Naval Academy	5	Escuela Tecnica Superios de Ingenieros de Camino Canalesy Puertos (Spain)	3
Utah, University of	3	Ethnikon Metsovion Polytechnion Athinaï (Greece)	2
Utah State University	1		
Valparaiso University	1		
Vanderbilt University	3		
Vassar College	3		
Vermont, University of	1		
Virginia, University of	3		
Virginia Commonwealth University	1		
Virginia Polytechnic Institute and State University	1		
Washington, University of	11		
Washington State University	1		
Washington University (Missouri)	1		
Wayne State University	1		
Webb Institute of Naval Architecture	2		
Wesleyan University (Connecticut)	1		

Fu Jen Catholic University (Republic of China)	1	Taiwan Provincial Taipei Institute of Technology (Republic of China)	1
Ha'Technion-Machon Technologi le Israel (Israel)	2	Tatung Institute of Technology (Republic of China)	1
Ha'Universita Ha'Ivrith Birushalayim (Israel)	3	Technische Hochschule (Austria)	1
Hitotsubashi Daigaku (Japan)	1	Technische Hogeschool Delft (The Netherlands)	2
Imperial College of Science and Technology (England)	2	Technische Universität Berlin (West Germany)	2
Indian Institute of Technology, Bombay (India)	1	Technische Universität München (West Germany)	2
Indian Institute of Technology, Kanpur (India)	1	Tohoku Daigaku (Japan)	1
Indian Institute of Technology, Kharagpur (India)	2	Tokyo Daigaku (Japan)	11
Institut d'Etudes Politiques (France)	2	Tokyo Geijutsu Daigaku (Japan)	1
Institut Industriel du Nord de la France (France)	1	Tokyo Kogyo Daigaku (Japan)	3
Institut National des Hydrocarbures and Chimie (Algeria)	1	Toronto, University of (Canada)	1
Instituto Politecnico Nacional (Mexico)	2	Universidad Anahuac Mexico (Mexico)	2
Instituto Tecnológico Autónomo de México (Mexico)	1	Universidad Católica de Chile (Chile)	2
Instituto Tecnológico y de Estudios Superiores de Monterrey (Mexico)	2	Universidad Central de Venezuela (Venezuela)	1
Instituto Tecnológico y de Estudios Superiores de Occidente (Mexico)	1	Universidad Complutense de Madrid (Spain)	2
Istanbul Teknik Üniversitesi (Turkey)	1	Universidad de Barcelona (Spain)	1
Jadavpur University (India)	1	Universidad de Buenos Aires (Argentina)	2
Jami'at Al-Riyad (Saudi Arabia)	1	Universidad de Chihuahua (Mexico)	1
Keio Gijuku Daigaku (Japan)	2	Universidad de Chile (Chile)	2
Kyoto Daigaku (Japan)	5	Universidad de los Americas (Mexico)	1
Kyushu Daigaku (Japan)	1	Universidad de los Andes (Colombia)	1
Lagos, University of (Nigeria)	2	Universidad de Oviedo (Spain)	1
Lancaster, University of (England)	1	Universidad Michoacana de San Nicolás de Hidalgo (Mexico)	1
Leeds, University of (England)	1	Universidad Nacional Autónoma de Honduras (Honduras)	1
London, University of (England)	1	Universidad Nacional Autónoma de México (Mexico)	1
Ludwig-Maximilians-Universität München (West Germany)	1	Universidad Nacional de Colombia (Colombia)	2
Manchester, University of, Institute of Science and Technology (England)	1	Universidad Politécnica de Barcelona (Spain)	1
McGill University (Canada)	7	Universidad Simón Bolívar (Venezuela)	1
Nagoya Daigaku (Japan)	2	Universidade de Amazonas (Brazil)	1
Nairobi, University of (Kenya)	2	Universidade de São Paulo (Brazil)	6
National Cheng-Kung University (Republic of China)	3	Universidade Federal de Minas Gerais (Brazil)	1
National Taiwan University (Republic of China)	3	Universidade Federal do Rio de Janeiro (Brazil)	1
National Tsing Hua University (Republic of China)	1	Università Commerciale Luigi Bocconi (Italy)	2
North London Polytechnic (England)	1	Universität Fridericiana Karlsruhe (West Germany)	2
Ottawa, University of (Canada)	1	Universität Hamburg (West Germany)	1
Oxford University (England)	2	Universität Tel-Aviv (Israel)	2
Pamantasan ng Pilipinas, (Philippines)	1	Université Catholique de Louvain (Belgium)	1
Panjab University (Pakistan)	1	Université d'Algers (Algeria)	1
Politechnika Warszawski (Poland)	1	Université de Bordeaux I (France)	2
Politecnico di Milano (Italy)	1	Université de Paris I (France)	1
Pontificia Universidad Javeriana (Colombia)	1	Université de Paris VI (France)	1
Puerto Rico, University of, Mayaguez (Puerto Rico)	6	Université de Paris VII (France)	1
Queen's University at Kingston (Canada)	1	Université du Québec à Montréal (Canada)	1
Rangoon Institute of Technology (Burma)	1	Université libre de Bruxelles (Belgium)	4
Rijksuniversiteit te Gent (Belgium)	1	Université Sains Malaysia (Malaysia)	1
Royal Military College (Canada)	1	University College (England)	1
Saint Andrew's School of Occupational Therapy (England)	1	University of Engineering and Technology (Pakistan)	1
Saint Mary's University (Canada)	1	Victoria, University of (Canada)	2
Scholi Naftikon Dokimon (Greece)	1	Waseda Daigaku (Japan)	2
Seoul Dae Hag Gyo (Republic of Korea)	5	Waterloo, University of (Canada)	4
Sheffield, University of (England)	2	Western Ontario, University of (Canada)	1
Staatliche Ingenieurschule (West Germany)	1	Witwatersrand, University of (South Africa)	2
Strathclyde, University of (Scotland)	1	Yonsei University (Republic of Korea)	1
			251
		Grand Total	1,212

¹Graduates of 220 Colleges and Universities in the United States and 148 Foreign Colleges and Universities entered the Institute.

Table VII Geographic Distribution of Students, 1976-1977

	Under-grad.	Grad.		Under-grad.	Grad.		Under-grad.	Grad.
United States			U.S. Territories and Dependencies			Jamaica	1	3
Alabama	9	13	Canal Zone	2	-	Japan	8	72
Alaska	6	-	Puerto Rico	27	19	Jordan	-	1
Arizona	22	12	Virgin Islands	1	-	Kenya	1	4
Arkansas	6	1	U.S. Citizens			Korea	20	29
California	204	155	Foreign Address	59	116	Lebanon	2	8
Colorado	41	19	Total U.S.	4,123	2,983	Libya	-	1
Connecticut	167	78	Foreign Countries*			Malaysia	12	15
Delaware	20	13	Afghanistan	-	1	Mexico	4	39
District of Columbia	18	20	Algeria	-	8	Morocco	-	2
Florida	79	50	Angola	-	1	Nepal	-	1
Georgia	32	21	Argentina	3	12	Netherlands	4	4
Hawaii	23	11	Australia	-	7	New Zealand	-	3
Idaho	5	5	Austria	-	3	Niger	-	1
Illinois	164	73	Bahama Islands	1	-	Nigeria	4	25
Indiana	28	16	Bangladesh	3	2	Norway	-	5
Iowa	29	12	Belgium	-	12	Pakistan	20	16
Kansas	30	12	Bermuda	1	-	Peru	4	5
Kentucky	23	6	Bolivia	1	-	Phillipines	2	3
Louisiana	26	12	Brazil	1	42	Poland	1	1
Maine	36	15	Brunei	-	1	Portugal	1	10
Maryland	114	56	Burma	-	1	Rumania	-	2
Massachusetts	710	1,302	Canada	42	75	Saudi Arabia	2	8
Michigan	107	61	Chile	1	15	Sierra Leone	-	1
Minnesota	40	18	China, Peoples Republic of	1	-	Singapore	1	-
Mississippi	5	1	China, Republic of	20	85	South Africa, Republic of	1	8
Missouri	56	19	Colombia	9	9	Spain	1	30
Montana	7	3	Costa Rica	1	2	Sri Lanka	4	2
Nebraska	13	7	Cuba	1	2	Sweden	3	5
Nevada	6	1	Cyprus	-	2	Switzerland	1	8
New Hampshire	34	25	Czechoslovakia	2	2	Tanzania	2	1
New Jersey	277	110	Denmark	-	4	Thailand	7	11
New Mexico	9	7	Ecuador	-	1	Trinidad	4	1
New York	779	293	El Salvador	-	1	Turkey	6	12
North Carolina	47	17	Ethiopia	1	4	Uganda	1	1
North Dakota	2	-	France	1	47	Union of Soviet Socialist Republics	1	
Ohio	152	59	Gambia	-	1	United Arab Republic (Egypt)	1	6
Oklahoma	16	6	Germany	6	19	United Kingdom	11	48
Oregon	29	7	Ghana	12	11	Uruguay	2	3
Pennsylvania	239	114	Greece	8	42	Venezuela	6	32
Rhode Island	22	18	Guatemala	-	1	Vietnam	3	4
South Carolina	16	7	Guyana	1	-	Yugoslavia	5	2
South Dakota	5	1	Haiti	-	1	Zaire, Republic of	-	1
Tennessee	27	18	Honduras	-	1	Stateless	9	7
Texas	122	37	Hong Kong	37	69	Total Foreign	345	1,146
Utah	1	8	Hungary	2	-	Grand Total	4,468	4,129
Vermont	11	9	Iceland	-	1			
Virginia	101	29	India	11	68			
Washington	65	30	Indonesia	2	6			
West Virginia	6	5	Iran	12	96			
Wisconsin	43	34	Iraq	2	-			
Wyoming	5	2	Ireland	-	4			
			Israel	5	27			
			Italy	3	18			
			Ivory Coast	-	1			

*Country of Citizenship

Table VIII Number of Degrees Awarded in September 1976, February 1977, and June 1977

	S.B.		S.M.		M. Arch. M.C.P.		M. Arch. A.S.		Engineer		Ph.D.		Sc.D.		Total						
	Sept.	June	Sept.	June	Sept.	June	Sept.	June	Sept.	June	Sept.	June	Sept.	June	Sept.	June					
School of Architecture and Planning																					
Architecture	-	-	-	-	7	4	24	2	3	19	-	-	-	-	9	7	43				
Undesignated	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-				
Art and Design	2	9	39	-	-	-	-	-	-	-	-	-	-	-	2	9	39				
Urban Studies and Planning	8	-	11	-	5	8	20	-	-	-	4	1	5	-	17	9	36				
Total	10	10	50	-	12	12	44	2	3	19	-	4	1	5	-	28	118				
School of Engineering																					
Aeronautics and Astronautics	-	3	11	11	12	16	-	-	-	-	1	-	-	2	3	1	19	20	28		
Ceramics	-	4	8	37	9	6	15	-	-	-	3	3	2	-	1	3	19	19	58		
Chemical Engineering	-	2	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	8		
Undesignated	-	-	-	-	16	15	-	-	-	-	-	-	-	-	-	-	-	-	15		
Chemical Engineering Practice	-	3	7	47	30	24	33	-	-	-	1	1	1	5	1	3	40	36	89		
Civil Engineering	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2		
Undesignated	14	19	48	-	-	-	-	-	-	-	-	-	-	-	14	19	48	-	48		
Computer Science and Engineering	17	15	97	-	-	-	-	-	-	-	-	-	-	-	17	15	97	-	97		
Electrical Engineering	-	-	-	24	38	71	-	-	-	6	13	16	11	7	10	3	41	59	100		
Electrical Engineering and Computer Science	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	2	-	2		
Environmental Engineer	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Environmental Engineering	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Materials Engineering	1	4	5	-	-	-	-	-	-	-	-	-	-	4	8	4	3	2	5		
Materials Science and Engineering	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1		
Undesignated	-	-	-	-	4	6	-	-	-	-	-	-	-	-	-	-	-	4	6		
Materials Science	14	13	52	18	24	29	-	-	-	2	2	3	1	6	4	1	38	49	89		
Mechanical Engineering	-	2	8	-	-	-	-	-	-	-	-	-	-	-	2	8	-	2	8		
Undesignated	-	-	-	1	3	1	-	-	-	-	-	-	-	-	-	-	1	3	1		
Metallurgy	-	-	1	3	12	16	-	-	-	-	-	-	-	-	3	12	17	-	17		
Naval Architecture and Marine Engineering	-	-	3	6	13	14	-	-	-	2	5	2	4	4	9	1	5	12	23	33	
Nuclear Engineering	2	2	8	4	5	5	-	-	-	1	1	24	3	2	2	-	10	10	39		
Ocean Engineering	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1		
Undesignated	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-		
Polymers	-	-	-	5	3	-	-	-	-	-	-	-	-	-	-	-	5	3	-		
Shipping and Shipbuilding Management	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Total	55	75	329	115	161	224	-	-	-	16	27	48	29	29	39	13	14	18	228	306	658

School of Humanities and Social Science

Economics	5	5	25	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	19	11	32	
Humanities and Engineering	-	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	
Humanities and Science	3	1	8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	1	8	
Linguistics	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5	1	-
Philosophy	-	-	5	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	6
Political Science	-	2	9	1	6	8	-	-	-	-	-	-	-	-	-	-	-	-	-	7	13	21	
Psychology	-	-	-	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	1	
Total	8	8	51	4	8	9	-	-	-	-	-	-	-	-	-	-	-	-	-	38	30	72	

Alfred P. Sloan School of Management

Management	-	9	39	15	16	181	-	-	-	-	-	-	-	-	-	-	-	-	-	16	25	232
School of Science	-	-	-	3	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	4	-
Biochemical Engineering	-	-	-	1	-	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Biochemistry	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Biology	-	-	-	-	1	4	-	-	-	-	-	-	-	-	-	-	-	-	-	5	10	10
Undesignated	-	6	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	20
Chemistry	1	7	33	6	1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	24	17	48
Earth and Planetary Sciences	-	2	15	2	5	7	-	-	-	-	-	-	-	-	-	-	-	-	-	7	8	26
Food Science and Technology	-	-	-	-	4	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4	2
Interdisciplinary Science Program	-	3	2	3	1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	4
Life Sciences	10	13	83	1	1	7	-	-	-	-	-	-	-	-	-	-	-	-	-	10	13	83
Mathematics	5	21	68	1	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	11	27	93
Meteorology	-	-	-	1	1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	3
Neural and Endocrine Regulation	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nutrition and Food Science	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2
Nutritional Biochemistry and Metabolism	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	3
Physics	-	-	-	5	4	7	-	-	-	-	-	-	-	-	-	-	-	-	-	5	4	7
Toxicology	9	13	62	2	5	8	-	-	-	-	-	-	-	-	-	-	-	-	-	27	29	85
Total	25	65	283	24	27	49	-	-	-	-	-	-	-	-	-	-	-	-	-	51	40	62
Operations Research	-	-	-	2	1	3	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	3
Without Course Specification	-	-	-	12	8	11	-	-	-	-	-	-	-	-	-	-	-	-	-	12	8	11

Awarded jointly with Woods Hole Oceanographic Institution

Biology	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Earth and Planetary Sciences	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	4
Meteorology	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ocean Engineering	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Grand Total	98	168	752	172	220	487	12	12	44	2	3	19	16	27	48	114	89	122	14	19	21	428
Total	395	137	395	3	11	8	11	8	11	2	12	8	11	1	3	11	1,493					

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 decade										Grand Total	Calendar year since 1973 (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-	1973	1974	1975	1976	1977*
School of Architecture and Planning¹																		
Architecture	-	12	24	162	188	233	223	23	-	-	-	-	2	17	-	-	-	-
Undesignated	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Architectural Engineering ²	-	-	-	-	-	108	64	-	-	-	-	-	-	-	-	-	-	-
Art and Design	-	-	-	-	-	-	-	-	-	26	-	324	-	-	-	-	-	-
Urban Studies	-	-	-	-	-	-	-	-	-	-	-	119	-	-	-	-	-	-
Undesignated	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	
Total	-	12	24	162	188	233	331	87	-	-	28	461	1,526	62	76	62	73	60
School of Engineering																		
Aeronautics and Astronautics ¹¹	-	-	-	-	-	-	68	287	526	395	556	164	1,996	13	17	21	13	14
Undesignated	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-
Building Engineering and Construction	-	-	-	-	-	32	32	99	114	131	-	-	376	-	-	-	-	-
Chemical Engineering	-	-	-	91	123	372	571	434	740	726	421	217	3,695	26	29	36	39	45
Undesignated	-	-	-	-	-	-	-	-	-	-	3	51	393	10	5	10	7	10
Chemical Engineering Practice	-	-	-	-	-	-	99	90	95	108	1	-	393	-	-	-	-	-
Civil Engineering	12	84	86	256	407	504	653	284	272	457	252	310	3,577	33	55	49	59	54
Undesignated	-	-	-	-	-	-	-	-	-	-	7	21	28	3	2	2	2	2
Computer Science and Engineering	-	-	72	335	349	468	1,000	719	1,218	1,518	1,941	1,332	8,952	224	213	216	137	112
Electrical Engineering	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-
Undesignated	-	-	-	-	28	84	133	56	-	-	-	-	301	-	-	-	-	-
Electrochemical Engineering ³	-	-	-	-	-	6	226	222	230	133	-	-	817	-	-	-	-	-
General Engineering	-	-	-	-	-	-	-	52	194	311	186	91	834	10	16	10	19	9
Materials Science and Engineering ⁴	-	-	-	-	-	-	-	-	-	-	1	18	19	4	2	2	-	1
Undesignated	5	40	147	329	502	623	797	602	1,164	1,049	563	345	6,166	37	40	52	69	65
Mechanical Engineering	-	-	-	-	-	-	-	-	-	-	12	88	100	14	13	10	10	10
Undesignated	-	-	-	-	-	-	1	4	-	-	-	-	5	-	-	-	-	-
Military Engineering	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mining Engineering and Metallurgy	8	44	64	74	250	129	174	137	-	-	69	33	880	-	7	5	7	1
Naval Architecture and Marine Engineering	-	-	-	43	133	69+	100	173	234	139	-	3	993	5	7	5	7	1
Nuclear Engineering	-	-	-	-	-	-	-	-	-	-	-	3	3	-	-	-	-	3
Ocean Engineering	-	-	-	-	-	-	-	-	-	-	-	40	40	4	2	14	9	10
Undesignated	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	1
Sanitary Engineering	-	-	-	29	54	123	34	20	4	-	-	-	264	-	-	-	-	-
Total	25	168	369	1,157	1,846	2,378	3,888	3,179	4,791	4,967	4,012	2,877	29,657	384	417	437	453	404

School of Humanities and Social Science

Economics	-	-	-	-	-	-	-	-	-	-	129	187	316	24	24	24	22	30
Science	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Humanities and Engineering or Science ⁵	-	-	-	-	-	-	-	-	-	61	152	100	313	-	-	-	-	-
Philosophy	-	-	-	-	-	-	-	-	-	-	49	412	726	43	35	25	23	13
Political Science ⁹	-	-	-	-	-	-	-	-	-	-	-	24	24	8	4	-	3	5
Total	-	-	-	-	-	-	-	-	-	61	201	755	578	1,595	91	81	58	55

Alfred P. Sloan School of Management⁶

Business and Engineering Administration Management ¹⁰	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	-	-	-	-	-	-	-	-	-	-	142	872	641	909	732	-	-	3,296
	-	-	-	-	-	-	-	-	-	-	172	565	430	1,167	65	57	59	52
Total	-	-	-	-	-	-	-	-	-	-	142	872	641	909	904	565	430	4,463

School of Science

Biology ⁷	-	3	11	25	27	49	57	129	74	116	16	-	-	-	-	-	-	-
Undesignated	-	-	-	-	-	-	-	-	-	-	-	251	251	41	49	47	36	26
Chemistry	2	27	80	154	151	111	141	166	232	207	307	331	1,909	45	51	52	61	40
Earth and Planetary Sciences ⁸	-	-	-	8	6	3	36	22	32	141	109	149	506	27	20	23	28	17
Undesignated	-	-	-	-	-	-	-	-	-	-	7	20	27	-	-	-	-	-
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	-	-	-	-	
Interdisciplinary Science Program	-	-	-	-	-	-	-	-	-	-	-	61	61	11	11	8	9	5
Life Sciences ⁷	-	-	-	-	-	-	-	-	-	-	291	620	911	100	102	102	110	96
Mathematics	-	-	-	-	-	-	-	19	48	72	220	831	688	1,878	122	117	107	86
Meteorology	-	-	-	-	-	-	-	-	56	38	-	-	94	-	-	-	-	-
Physics	-	5	6	24	19	21	49	170	306	617	1,079	673	2,969	104	75	85	106	75
Total	4	46	114	260	223	210	319	608	865	1,463	2,651	2,793	9,556	450	425	424	436	348

Grand Total

	29	226	507	1,579	2,257	2,963	5,410	4,515	6,626	7,535	8,011	7,139	46,797	1,052	1,038	1,040	1,069	919
--	----	-----	-----	-------	-------	-------	-------	-------	-------	-------	-------	-------	--------	-------	-------	-------	-------	-----

*Includes only February and June degrees

¹Two received the degree in Naval Architecture, Course XIII-B, in 1916 and three in 1917

²See also Table XI

³Prior to 1923 degrees were awarded in Architecture

⁴Prior to 1909 this course was designated as Option 3 (Electrochemistry) or Physics

⁵Prior to 1938 these degrees were included in Mining Engineering and Metallurgy; changed from Metallurgy to Metallurgy and Materials Science, January 1968; changed to Materials Science and Engineering 1975

⁶Prior to 1958 these degrees were included in General Engineering and General Science or General Course

⁷Changed to Alfred P. Sloan School of Management in 1963

⁸Changed to Life Sciences beginning January 1962

⁹Changed from Geology and Geophysics to Earth Sciences in February 1961, changed from Earth Sciences to Earth and Planetary Sciences in February 1970

¹⁰Prior to September 1965, these degrees were included in Economics, Politics and Engineering or Science

¹¹Prior to 1959, Business and Engineering Administration, changed from Industrial Management to Management in February 1967

¹²Prior to 1960 Aeronautical Engineering

Table X Number of Degrees of Master of Science Awarded

	Total by decade										Grand Total	Calendar year since 1973 (included in decade total)				
	1886-90	1891-1900	1901-10	1911-20	1921-30	1931-40	1941-50	1951-60	1961-70	1971-		1973	1974	1975	1976	1977*
School of Architecture and Planning¹																
Architecture	-	8	45	31	-	-	-	-	-	-	-	-	-	-	-	
Architectural Engineering ²	-	-	-	-	9	10	-	-	-	-	-	-	-	-	-	
Total	-	8	45	31	9	10	-	-	-	-	-	-	-	-	-	
School of Engineering																
Aeronautics and Astronautics ^{1,11}	-	-	7	43	462	474	546	1,164	1,529	782	5,007	123	107	95	126	109
Building Engineering and Construction	-	-	-	-	16	8	-	-	-	-	28	-	-	-	-	-
Ceramics	-	-	-	-	15	11	-	-	-	19	26	-	2	11	4	2
Chemical Engineering	-	3	2	18	69	152	275	467	398	155	1,539	20	17	15	24	21
Chemical Engineering Practice	-	-	-	-	245	284	241	256	102	204	1,332	25	43	40	33	31
Civil Engineering	-	1	4	27	53	179	194	350	548	471	1,827	56	71	70	104	57
Electrical Engineering and Computer Science (including VI-A) ¹²	-	-	7	43	462	474	546	1,164	1,529	782	5,007	123	107	95	126	109
Electrochemical Engineering	-	-	-	4	16	8	-	-	-	-	28	-	-	-	-	-
Fuel and Gas Engineering	-	-	-	-	15	11	-	-	-	-	26	-	2	11	4	2
Materials Engineering	-	-	-	-	-	-	-	-	-	19	19	-	2	1	4	10
Materials Science	-	-	-	-	-	-	-	-	-	21	21	2	1	4	4	10
Mechanical Engineering	-	1	8	22	100	175	357	525	690	464	2,342	64	66	66	67	53
Metallurgy	-	-	-	-	8	36	92	230	205	72	643	14	12	6	3	4
Mining Engineering	-	-	-	9	8	16	-	-	-	-	33	-	-	-	-	-
Naval Architecture and Marine Engineering	-	-	2	1	5	20	60	165	281	164	698	23	24	26	26	28
Naval Construction and Engineering	-	-	39	48	101	89	206	67	282	214	483	34	35	39	29	27
Nuclear Engineering ³	-	-	-	-	-	-	-	-	3	103	106	22	17	24	19	10
Ocean Engineering	-	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-
Petroleum Engineering	-	-	-	-	-	5	-	-	-	5	5	-	-	1	4	-
Polymerics	-	-	-	-	-	14	-	-	-	-	14	-	-	-	-	-
Railroad Engineering	-	-	-	-	-	14	-	-	-	-	14	-	-	-	-	-
Sanitary Engineering	-	-	2	8	3	10	53	99	16	-	191	-	-	-	-	-
Shipping and Shipbuilding Management	-	-	-	-	-	-	-	4	15	39	58	4	2	7	18	3
Textile Technology	-	-	-	-	-	1	31	34	20	10	96	3	3	2	-	-
Total	-	5	64	197	1,144	1,553	2,386	3,815	4,775	3,029	16,968	443	443	438	502	385

School of Humanities and Social Science

Economics ⁷	-	-	-	-	-	-	-	-	-	19	15	34	1	3	1	2	2
Economics and Engineering or Science ¹⁰	-	-	-	-	-	12	16	19	19	10	-	57	-	-	-	-	-
Linguistics	-	-	-	-	-	-	-	-	-	1	7	8	2	1	3	-	-
Philosophy	-	-	-	-	-	-	-	-	-	7	7	7	1	2	2	1	-
Political Science ⁷	-	-	-	-	-	-	-	-	-	25	64	89	8	8	12	11	14
Psychology ⁴	-	-	-	-	-	-	-	-	-	7	7	14	2	1	-	1	1
Total	-	-	-	-	-	12	16	19	64	100	211	14	15	18	15	17	17

Alfred P. Sloan School of Management⁵

Management ⁸	-	-	-	-	4	60	122	581	1,274	1,250	3,291	195	183	184	161	207
-------------------------	---	---	---	---	---	----	-----	-----	-------	-------	-------	-----	-----	-----	-----	-----

School of Science

Biochemical Engineering	-	-	-	-	-	-	-	-	17	18	35	1	3	1	4	4
Biochemistry	-	-	-	-	-	-	-	3	6	4	13	1	-	1	3	-
Biology	-	1	1	10	1	19	25	29	12	37	135	10	4	5	2	5
Biophysics	-	-	-	-	-	-	-	2	3	1	6	1	-	-	-	-
Chemistry	2	3	7	22	32	51	53	46	97	53	366	5	6	11	9	4
Earth and Planetary Sciences	-	-	-	-	-	-	-	-	7	66	73	11	7	8	10	12
Food Technology	-	-	-	-	-	-	-	12	44	3	59	-	-	-	-	-
Food Science and Technology	-	-	-	-	-	-	-	-	57	30	87	4	3	2	3	6
General Science	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Geology and Geophysics ⁹	-	-	2	5	21	15	17	48	71	-	179	-	-	-	-	-
Interdisciplinary Science Program	-	-	-	-	-	-	-	-	-	11	11	-	-	-	7	4
Mathematics ⁶	-	-	-	2	9	25	45	96	73	44	294	7	-	6	9	8
Meteorology	-	-	-	-	-	35	99	118	87	52	391	14	7	7	6	4
Neural and Endocrine Regulation	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	1
Nutrition	-	-	-	-	-	-	-	-	23	-	23	-	-	-	-	-
Nutritional Biochemistry and Metabolism	-	-	-	-	-	-	-	7	25	61	93	10	7	10	16	11
Oceanography	-	-	-	-	-	-	-	-	28	17	45	1	3	3	-	-
Physics	-	3	2	2	16	40	50	121	138	99	471	19	10	15	9	13
Toxicology	-	-	-	-	-	-	-	-	-	4	4	-	-	-	-	4
Total	2	8	12	41	79	185	301	514	647	498	2,287	84	50	69	78	76

Operations Research Without Course Specification	-	-	-	-	5	308	263	123	357	299	56	5	13	8	9	4
--	---	---	---	---	---	-----	-----	-----	-----	-----	----	---	----	---	---	---

Grand Total	2	21	121	274	1,544	2,083	2,948	5,286	7,061	5,187	24,527	778	733	754	793	708
-------------	---	----	-----	-----	-------	-------	-------	-------	-------	-------	--------	-----	-----	-----	-----	-----

* Includes only February and June degrees

¹ See 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 Considered Engineering until 1956

⁷ Prior to September 1965 these degrees were included in Economics, Politics and Engineering or Science

⁸ Prior to February 1967 Industrial Management

⁹ Changed to Earth and Planetary Sciences beginning February 1970

¹⁰ Includes six degrees in Political Science awarded 1965

¹¹ Prior to 1960 Aeronautical Engineering

¹² Changed from Electrical Engineering to Electrical Engineering and Computer Science 1975

Table XI Number of Degrees of Bachelor and Master in Architecture and Bachelor and Master in City Planning

	Total by decade										Calendar year since 1973 (included in decade total)				
	1921-30	1931-40	1941-50	1951-60	1961-70	1971-	Grand Total	1973	1974	1975	1976	1977*			
Bachelor in Architecture ²	-	146	126	257	188	5	722	-	-	-	-	-			
Bachelor in City Planning ¹	-	14	13	4	-	-	31	-	-	-	-	-			
Master in Architecture ³	63	81	78	191	214	21	648	-	-	-	-	-			
Master of Architecture	-	-	-	-	23	177	200	23	19	27	38	28			
Master of Architecture in Advanced Studies	-	-	-	-	-	120	120	18	21	18	19	22			
Master in City Planning	-	18	82	114	152	202	568	29	25	39	32	28			
Grand Total	63	259	299	566	577	525	2,289	70	65	84	89	78			

*Includes only February and June degrees

¹From 1935 to 1944, Bachelor of Architecture in City Planning

²Degree of Bachelor in Architecture changed to degree of Master of Architecture in 1972

³Degree 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 decade					Grand Total	Calendar year since 1973 (included in decade total)				
	1949-60	1961-70	1971-	1973	1974		1975	1976	1977*		
Engineer in Aeronautics and Astronautics ¹	35	58	20	113	2	4	4	3	-		
Building Engineer ³	5	2	-	7	-	-	-	-	-		
Chemical Engineer	17	31	49	97	12	7	5	8	5		
Civil Engineer	21	78	57	156	10	5	4	6	2		
Electrical Engineer	132	444	286	862	42	44	32	41	29		
Environmental Engineer	-	-	9	9	1	2	2	2	2		
Marine Mechanical Engineer	7	2	1	10	-	-	-	-	-		
Materials Engineer	-	7	3	10	-	-	1	1	-		
Mechanical Engineer	102	166	83	351	18	15	10	6	5		
Metallurgical Engineer	24	18	6	48	2	1	-	-	-		
Meteorologist ²	2	-	-	2	-	-	-	-	-		
Naval Architecture	11	21	17	49	1	1	8	3	-		
Naval Engineer	334	246	20	600	-	-	1	-	-		
Nuclear Engineer	-	37	36	73	5	7	4	6	7		
Ocean Engineer	-	4	135	139	25	23	14	24	25		
Sanitary Engineer ³	9	3	-	12	-	-	-	-	-		
Total	699	1,117	722	2,538	118	109	85	100	75		
Awarded jointly with Woods Hole Oceanographic Institution											
Ocean Engineer	-	-	11	11	2	-	4	-	-		
Grand Total	699	1,117	733	2,549	120	109	89	100	75		

*Includes only February and June degrees
¹Prior to 1960 Aeronautical Engineer
²Degree discontinued after 1955
³Degrees discontinued after 1964

Table XIII Number of Degrees of Doctor of Philosophy Awarded

	Total by decade										Calendar year since 1973 (included in decade total)			
	1907-10	1911-20	1921-30	1931-40	1941-50	1951-60	1961-70	1971-	Grand Total	1973	1974	1975	1976	1977*
School of Architecture and Planning														
Architecture	-	-	-	-	-	-	-	1	1	-	-	-	-	-
Urban Studies and Planning ⁶	-	-	-	-	-	-	24	40	64	6	8	7	6	6
Total	-	-	-	-	-	-	24	41	65	6	8	7	6	6
School of Engineering														
Aeronautics and Astronautics ⁷	-	-	-	-	-	6	57	68	131	13	11	12	11	2
Chemical Engineering	-	-	-	-	-	-	31	27	58	7	6	3	2	2
Civil Engineering	-	-	-	-	-	1	72	92	165	16	11	16	12	8
Electrical Engineering and Computer Science ⁹	-	-	-	-	1	9	248	239	497	40	30	44	27	17
Materials Science and Engineering ³	-	-	-	-	-	6	103	90	199	14	10	9	7	12
Mechanical Engineering	-	-	-	-	-	4	95	99	198	8	16	16	16	10
Nuclear Engineering	-	-	-	-	-	5	90	70	165	7	6	9	17	13
Ocean Engineering ⁸	-	-	-	-	-	-	15	22	37	3	2	-	5	4
Sanitary Engineering	-	-	-	-	-	2	3	-	5	-	-	-	-	-
Total	-	-	-	-	1	33	714	707	1,455	108	92	109	97	68
School of Humanities and Social Science														
Economics ¹	-	-	-	-	19	96	195	136	446	20	19	18	25	11
Group Psychology	-	-	-	-	8	1	-	-	9	-	-	-	-	-
Linguistics	-	-	-	-	-	-	35	48	83	6	11	7	9	1
Philosophy	-	-	-	-	-	-	8	19	27	4	3	3	2	3
Political Science	-	-	-	-	-	-	71	74	145	10	12	12	12	9
Psychology	-	-	-	-	-	3+	24	31	58	5	2	7	7	2
Total	-	-	-	-	27	100	333	308	768	45	47	47	55	26

Alfred P. Sloan School of Management
Management²

	-	-	-	-	-	-	-	-	-	-	89	68	157	10	10	19	8	2
School of Science	-	1	10	17	21	38	105	113	305	11	16	14	15	15	15	15	15	15
Biology	7	19	59	146	180	342	427	300	1,480	52	39	32	43	21	21	21	21	21
Chemistry	1	7	10	22	20	71	84	62	277	3	10	13	12	5	5	5	5	5
Earth and Planetary Sciences ⁴	-	-	6	25	35	70	211	164	511	31	22	18	23	23	23	23	23	23
Mathematics	-	-	-	-	-	-	14	45	87	1	7	2	4	2	2	2	2	2
Meteorology	-	-	-	-	4	28	66	87	185	18	15	9	17	12	12	12	12	12
Nutrition and Food Science	-	-	-	-	-	-	11	-	11	-	-	-	-	-	-	-	-	-
Oceanography ⁵	-	-	2	6	48	159	283	390	1,160	38	34	32	47	24	24	24	24	24
Physics	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	8	29	91	258	419	846	1,339	1,026	4,016	154	143	120	161	102	102	102	102	102

Awarded jointly with Woods Hole
Oceanographic Institution

Biology	-	-	-	-	-	-	-	5	5	-	-	2	3	-	-	-	-	-
Earth and Planetary Sciences	-	-	-	-	-	-	4	26	30	6	2	6	6	4	4	4	4	4
Meteorology	-	-	-	-	-	-	1	12	13	-	-	3	1	2	2	2	2	2
Ocean Engineering	-	-	-	-	-	-	-	3	3	-	-	1	1	1	1	1	1	1
Total	-	-	-	-	-	-	5	46	51	6	2	12	11	7	7	7	7	7
Grand Total	8	29	91	258	447	979	2,504	2,196	6,512	329	302	314	338	211	211	211	211	211

*Includes only February and June degrees

†Previously included in Industrial Economics

1 Changed from Industrial Economics to Economics 1966

2 Changed from Industrial Economics to Management 1967

3 Changed from Industrial Management to Management 1967

4 Includes Ceramics, Metallurgy and Materials Science changed to Materials Science and Engineering 1975

5 Changed from geology and Geophysics to Earth and Planetary Sciences 1970

6 Beginning 1967-68 included in Earth and Planetary Sciences or Meteorology

7 Changed from City and Regional Planning to Urban Studies and Planning September 1969

8 Prior to 1960 Aeronautical Engineering

9 Changed from Naval Architecture and Marine Engineering to Ocean Engineering September 1971

Changed from Electrical Engineering and Computer Science 1975

Table XIV Number of Degrees of Doctor of Science Awarded

School of Engineering	Total by decade										Calendar year since 1973 (included in decade total)				
	1911-20	1921-30	1931-40	1941-50	1951-60	1961-70	1971-	Grand Total	1973	1974	1975	1976	1977*		
Aeronautics and Astronautics ¹	2	4	5	18	31	76	36	172	6	4	4	7	4		
Chemical Engineering	-	23	78	114	117	151	59	542	9	8	7	9	4		
Civil Engineering	-	2	12	23	46	75	34	192	3	7	3	3	4		
Electrical Engineering and Computer Science ⁵	3	12	30	34	141	124	51	395	7	8	8	5	4		
Electrochemical Engineering	-	1	1	-	-	-	-	2	-	-	-	-	-		
Materials Science and Engineering ⁶	-	14	32	86	194	201	67	594	11	6	8	15	5		
Mechanical Engineering	-	4	13	35	125	145	59	381	6	10	9	11	5		
Mineral Engineering	1	-	4	-	-	-	-	5	-	-	-	-	-		
Nuclear Engineering	-	-	-	-	9	55	36	100	6	2	2	5	6		
Ocean Engineering ⁴	-	1	-	-	2	6	9	18	-	1	4	-	-		
Petroleum Engineering	-	-	1	-	-	-	-	1	-	-	-	-	-		
Sanitary Engineering	-	-	2	3	18	2	-	25	-	-	-	-	-		
Total	6	61	178	313	683	835	351	2,427	48	46	45	55	32		
School of Science															
Chemistry	-	2	5	4	3	1	2	17	-	-	-	1	-		
Earth and Planetary Sciences ²	1	2	4	5	2	3	5	22	-	-	2	1	-		
Mathematics	-	2	3	-	1	1	2	9	-	-	-	-	-		
Meteorology	-	-	6	25	17	6	6	60	-	-	2	1	2		
Nutrition and Food Science	-	-	-	3	10	17	17	47	3	3	-	1	3		
Oceanography ³	-	-	-	-	-	1	-	1	-	-	-	-	-		
Physics	-	5	18	14	7	7	10	61	1	1	2	2	2		
Total	1	11	36	51	40	36	42	217	4	4	6	6	7		
Awarded jointly with Woods Hole Oceanographic Institution															
Earth and Planetary Sciences	-	-	-	-	-	-	1	1	-	-	-	-	1		
Meteorology	-	-	-	-	-	-	4	4	1	1	-	-	-		
Grand Total	7	72	214	364	723	871	398	2,649	53	51	51	71	40		

*Includes only February and June degrees
¹Prior to 1960 Aeronautical Engineering
²Changed from Geology and Geophysics to Earth and Planetary Sciences 1970
³Beginning 1967-68 included in Earth and Planetary Sciences or Meteorology
⁴Changed from Naval Architecture and Marine Engineering to Ocean Engineering 1970
⁵Changed from Electrical Engineering to Electrical Engineering and Computer Science 1975
⁶Changed from Metallurgy and Materials Sciences to Materials Science and Engineering 1975

Table XV Summary of Degrees Awarded
(1868-1977)

Bachelor in Architecture (discontinued 1972)	722
Bachelor in City Planning (discontinued 1954)	31
Bachelor of Science	46,797
Master in Architecture (discontinued 1972)	648
Master in City Planning	568
Master in Public Health (discontinued 1944)	104
Master of Architecture	200
Master of Architecture in Advanced Studies	120
Master of Science	24,527
Advanced Engineering	2,538
Advanced Engineering awarded jointly with Woods Hole Oceanographic Institution	11
Doctor of Engineering (discontinued 1918)*	4
Doctor of Philosophy	6,461
Doctor of Philosophy awarded jointly with Woods Hole Oceanographic Institution	51
Doctor of Public Health (discontinued 1944)*	9
Doctor of Science	2,644
Doctor of Science awarded jointly with Woods Hole Oceanographic Institution	5
	<hr/>
	85,440

*See 1959 Report of the Registrar for details.

Warren D. Wells

Office of the President and the Chancellor

The annual reports that appear in this section are submitted by the heads of administrative departments and operations which report directly to the Office of the President and the Chancellor. The Council for the Arts at M.I.T. reports to the President through Professor Roy Lamson, Special Assistant to the President for the Arts. The Director of Information Processing Services reports directly to the Chancellor. The Institute Information Services and the M.I.T. Press report to Constantine B. Simonides, Vice President in the Office of the President and the Chancellor. The Director of the Plasma Fusion Center reports to the President.

Council for the Arts

The year 1976-77, the Council's fourth full operating year, was one of continuing development for the arts at M.I.T. A staff of five -- Professor Roy Lamson, Special Assistant to the President for the Arts; Peter Spackman, Executive Director; Susan Knight, Associate Director; Annette Anderson, Assistant Director; and Rebecca Burke, Secretary -- worked with Council members, faculty, and students to expand the range of artistic activities at the Institute, and with members of M.I.T.'s Resource Development staff to help realize arts related goals in the Institute's Leadership Campaign.

The Program and Information Committee, chaired by Dr. Leo Beranek, made 13 grants totaling \$22,852 to a wide variety of programs in the arts at M.I.T. Grant recipients included the M.I.T. Symphony Orchestra for additional support of their recording project with Vox Records; the M.I.T. Shakespeare Ensemble for assistance in funding their East Coast tour in January; the Committee on the Visual Arts for funding the Peter Campus exhibit, Mask Projections; and the Dance Workshop for support of its yearly activities. Additional grants supported the Music Section's 1976-77 concert series; provided assistance for a set of performances of Paul Earls' chamber operas, Grimm Duo; provided for the purchase of a collection of renaissance and baroque musical instruments for M.I.T.'s Early Music Ensemble; provided matching support for a film-essay of sculptor Larry Bell's experiences at the Institute; and assisted in supporting the Hayden Gallery exhibition "Women in Architecture."

The Museum and Acquisitions Committee, under the chairmanship of Ida Rubin, continued to work closely with M.I.T.'s Committee on the Visual Arts. Of particular note during the year was the loan to M.I.T. of "The Iceberg and Its Shadow" by California sculptor Larry Bell. Vera List, a member of the Museum and Acquisitions Committee, arranged for the extended loan of this monumental work, which is part of the Albert and Vera List Family Collection. "The Iceberg" was shown in its entirety (56 plates of coated glass) in Hayden Gallery during January and February. Eight of the plates have been rearranged to form a smaller version of "The Iceberg," and the work remains on view in the lobby of the Sloan Building.

In September, a major work by the internationally celebrated British sculptor Henry Moore was installed in the Killian Court. The sculpture, entitled "Three Piece Reclining Figure,

Draped, " is a gift of the Eugene McDermott family of Dallas, Texas, for whom the Council's Eugene McDermott Award for contributions to the arts at M. I. T. is named.

The Planning and Facilities Committee met during the year to review the Arts Environments Study and to make recommendations to the Council's Executive Committee and to the President for its use. The Committee prepared a formal statement outlining a major plan of action for implementing portions of the Arts Environments Study, which was presented to the entire Council body at the annual meeting as a task to be undertaken within the context of M. I. T.'s ongoing Leadership Campaign.

The Financial Development Committee worked throughout the year to develop fund raising plans for the arts that are consistent with the plans and operations of M. I. T.'s Leadership Campaign. Within the framework of the larger campaign, the Committee set up a network of fund raising units in major cities throughout the United States to begin seeking both new gifts -- those gifts not normally attracted to M. I. T. -- and large gifts in the "Leadership Gift" category or above. At the end of fiscal year 1977, results began to accrue as the Council experienced a giving level nearly twice that of the previous year in terms of both dollars and number of donors.

Seven new members were nominated by the Membership Committee and were appointed to the Council for the Arts by President Jerome B. Wiesner for three-year terms. They are James A. Champy, Class of 1963, of Boston; Virginia Duncan of San Francisco; Ernest A. Grunsfeld III, Class of 1952, of Chicago; John O. Merrill, Jr., Class of 1949, of San Francisco; Agnes Saalfield of Boston; Cynthia Tobias, Class of 1972, of Boston; and William Turnbull, Jr., of San Francisco. Total Council membership at the end of the year was 78.

In addition to work done through the standing committees, the Council for the Arts continued publication of the monthly calendar of arts events at M. I. T. (circulation 1,000); jointly sponsored a tour of the East Coast by the M. I. T. Shakespeare Ensemble; and sponsored cultural events for M. I. T. alumni at the Art Institute of Chicago and the Los Angeles County Museum of Art.

During the January Independent Activities Period, the M. I. T. Shakespeare Ensemble toured the East Coast, performing The Taming of the Shrew for alumni groups in Hartford, northern New Jersey, Princeton, Philadelphia, Baltimore, and Washington, DC. The tour was cosponsored by the Council for the Arts and the Alumni Association with assistance from the Educational Council and alumni clubs in each community. In addition to the full-length performances for alumni clubs, four scene-shows were presented in local high schools for nearly 1,000 students who participated later in informal discussions with Ensemble members about student life and education at M. I. T. The Ensemble was received enthusiastically throughout the entire tour by both alumni and high-school teachers and students. As summed up by one high-school principal: "The experience [of the performance] has done much to bring Shakespeare alive for so many of our students, as well as to reveal a cultural and humanistic side of M. I. T. which, for many of us, has been in the shadow of its scientific excellence."

Cultural events sponsored by the Council for the Arts for alumni in Chicago and Los Angeles centered around the American Revolution Bicentennial Administration's official exhibition, "The World of Franklin and Jefferson." Designed by the Office of Charles and Ray Eames, the exhibition toured Europe and America for two years during the time of the United States Bicentennial celebrations. While on exhibit at the Art Institute of Chicago in July and the Los Angeles County Museum of Art in December, the Council arranged for private showings of the exhibition for M. I. T. alumni in each city. The two gala evenings, which attracted more than 300 alumni in Chicago and over 400 alumni in Los Angeles, included a speaking program in which President Wiesner and Mr. Eames discussed aspects of "Government and the Mind." Both events, well-received by local alumni, have helped to establish a model for cultural events which the Council hopes to repeat in future years in other cities.

A particular highlight of the Council's year was the fifth annual meeting, held on Friday, November 19. The annual business meeting was opened by Chairman Luis Ferré who announced to the group of 55 Council members the Executive Committee's formal recommendation that the Council for the Arts take a strong and active part in M. I. T. 's current Leadership Campaign to help realize the various arts related goals. Dr. Wiesner and Professor Walter Rosenblith spoke on the general needs of the arts in the areas of endowment and program funding, and Dr. Beranek and Professor Donlyn Lyndon presented an analysis of specific arts facilities needs, as outlined in the Arts Environments Study. The Council members discussed the Institute's needs and how the Council most effectively could join the efforts of the Leadership Campaign. Questions concerning the Campaign were answered by Nelson Lees, Director of Resource Planning, and Donald Severance, Director of the Volunteer Leadership Appeal. The business meeting concluded with a formal resolution that the Council for the Arts begin to work with the Leadership Campaign to further the objectives of arts at M. I. T. in the areas of endowment, programming, and facilities.

At lunch in the Sala de Puerto Rico in the Stratton Student Center, the Council met with faculty and students in the arts at M. I. T. and with Leadership Campaign District Officers. After lunch, the Council members heard a panel discussion presented by Harold Hanham, Dean of the School of Humanities and Social Science, William L. Porter, Dean of the School of Architecture and Planning, and several of their colleagues concerning current programs in the arts and projected needs. Following the panel discussion, the Council gathered for the dedication of the Louis Skidmore Room for the Rotch Library's Visual Collection.

The Council's annual dinner at the President's House was the occasion for announcing the third Eugene McDermott Award, which carries with it a cash award of \$1,000 and is presented by the Council annually "for major contributions to the arts as a means of human fulfillment." Council member Ida Rubin, chairman of the McDermott Award Committee, reported that the Committee had recommended unanimously and the Executive Committee approved that the 1976 recipient be Paul Tishman, Class of 1924, first Chairman of the Council for the Arts. Mr. Tishman received the Award in September while Mrs. Margaret McDermott was at M. I. T., however the Council, at this time, acknowledged once again his great contributions to the development of the arts at M. I. T. After dinner, the annual meeting concluded with remarks by David Rockefeller, Jr. who spoke on the topic of the arts and education.

The past year was a very full one for the Council staff and members, as well as for the many students and faculty engaged in the arts, a year in which we came a little bit closer to the ultimate goal of both enhancing the M. I. T. community as a whole, and helping to provide students with experiences in the arts that will complement the depth and insight of their experiences in science and engineering.

PETER SPACKMAN

Information Processing Services (I.P.S.)

In June 1977 the Information Processing Services completed its first year of operation as an integral unit, reorganized under functional lines, which encompass those responsibilities formerly shared by three departments, the Information Processing Center, the Office of Administrative Information Systems, and the Programming Development Office. There can be no doubt that this reorganization has resulted in better communication and closer

cooperation of personnel not only within I. P. S. but also between the organization and the computer-using community.

Two new appointments were made to direct the activities of the two main avenues of service, the Administrative Computing Services and the Academic and Research Computing Services. David Carney, who formerly acted as Assistant Director of the Office of Administrative Information Systems, was appointed Director of Administrative Computing Services; and Jean Bonney, formerly of Rutgers University, was appointed Director of Academic and Research Computing Services. It is through these two organizations that the I. P. S. delivers production data processing and computer related services to the Institute at large.

In support of these activities, the planning and development of language processors, operating systems, hardware, and new administrative systems are done by four separate groups: Systems Programming, managed by Roger Roach; Business Systems Development, managed by Paul Saia; Special Projects and Planning, coordinated by James Donohue; and Computer Operations, managed by Leo Ryan.

With this new format, and with the financial controls provided by Charles W. Libby, Manager of Administration, the I. P. S. was able to reduce its operating cost by over \$170,000, and to balance the revenues versus expenses of the entire operation.

Administrative Computing Services

For the first time in more than three years, major progress has been made in overcoming the backlog of program modifications of production information systems. Part of this accomplishment is due to the closer coordination exerted by systems analysts in determining total client requirements, so that multiple changes now can be appropriately packaged as a single modification. In addition, we have been able to acquire some very talented and aggressive analysts and programmers.

Maintenance and modification of existing production systems will be charged to client offices next year, and in anticipation of this, many of our users are becoming more cost conscious and are beginning to evaluate the worth of certain changes.

As mentioned in last year's Report, we are continuing the conversion and rewrite of many old applications in anticipation of running all our administrative work under the OS/370 Operating System rather than under the DOS/370 System, with no reliance on any form of simulation or emulation. This process should continue until fall, 1978, at which time we anticipate greatly reducing costs by utilizing the central facility and through capitalizing on the economies of scale.

Some major hardware decisions were made during the year, not only to reduce costs but also to assist in the operating system conversion mentioned before. In the area of disk files, tape drives, display terminals, and controllers, we have negotiated long-term lease agreements, outright purchases, installment purchases, and the acquisition of plug compatible hardware from other vendors. These dollar savings are, of course, not only beneficial during this year but will be cumulative in years to come. Regarding the central processor, we plan a major change during mid-October of 1977 when we will replace the existing IBM Model 145 computer with a Model 148. With this new hardware we will be able to run two operating systems at the same time so that new applications as well as the old converted ones can run under OS, while a DOS System is still available until the conversion is complete. The Model 148 is one of IBM's most modern computers and brings with it new printing capabilities on which we plan to capitalize. Sufficient financial savings were made in areas other than in the processor, such that virtually no incremental operating cost will be experienced.

During fiscal year 1977 we made a major effort to address the need for improved and standardized documentation for administrative computing. The Documentation Manager's position was defined with specific responsibilities, and the position description was approved by the Institute's Classification Review Committee. The position was filled by Frank Melanson, a former Systems Analyst and Project Manager.

Operationally we continue to maintain an extremely high level of jobs completed correctly and on time. For the 12 months ending June 1977, 97 percent of all jobs were returned error-free and on time. This is 2.5 percent better than the 94.5 percent reported last year.

Business Systems Development

In the area of new business information systems, we have analyzed the information needs within the Admissions Office and the Student Financial Aid Office, and produced feasibility studies in each case. The Admissions system has been modified to use key-to-tape equipment, which greatly reduced a data entry bottleneck.

In addition to these two studies we plan to install a new accounts receivable system in November 1977 and to utilize our new payroll system procedures in the production running of the pension payroll early this fall.

A major effort has begun in the development of a budget and account reporting system. This project is being undertaken in conjunction with the Sloan School of Management's Center for Information Systems Research under the direction of Dr. John Rockart. This is the first opportunity we have had to try to combine the talents of both the academic and the administrative staffs to develop an information system that provides not only an excellent real-world case for the Center but that also offers exposure to the field of systems research for our staff.

Academic and Research Computing Services

Service to the academic and research community continued during the year with the support of an extensive library of applications software, individual user consulting, and the teaching of non-credit computer related courses.

During the year we suffered an exceptional staff turnover which, coupled with the new organizational structure, caused us to spend more time than we had planned in searching for candidates and acclimating new people to the environment. Brenda Ferriero was promoted from Computer Services Coordinator to the critical position of Supervisor of User Services.

In spite of these difficulties we have been able to pursue some interesting and challenging projects. One of these is the exploitation of the TELENET communications network in conjunction with EDUCOM. In this area we have made over 200 mailings to other colleges and universities, enclosing over 50 pages of documentation covering M.I.T.'s computer offerings. The specially prepared manuals and sample program sets covered the following areas: access to M.I.T.'s computing via TELENET; a Remote User Guide to M.I.T. Computing; the Multics Time-sharing System; MACSYMA, a symbolic mathematics package; the educational computing system ECS; APL under Multics; and the text formatting and word processing systems QEDX and RUNOFF. This endeavor was a first for Information Processing Services in the area of marketing. Although we have not received a high volume of new remote usage, the experience of addressing the off-campus community offered new insight into promoting the use of computers locally. Campus computer users, like those at distant locations, have developed into a time-sharing community in which communication, documentation, and con-

sultation becomes more difficult. This year we have concentrated on serving the user in his or her area rather than at the computer center, as has been done in the past. We plan to continue this procedure in the years to come. In addition, new ways of addressing the non-technical computer user must be developed. Through the networking experience we have determined that our Multics System offers interesting possibilities in the areas of limited access, encapsulated environments, special pricing, and distributed user services.

Systems Programming

Systems programming activities during the year concentrated as in the past, on the support of language processors and operating systems. Major activities, however, involve the systems assurance function of all new releases of the Multics operating system in close conjunction with Honeywell Information Systems' Cambridge Information Systems Laboratory. This activity consists of installing and testing at least 40 major changes per year involving over 1,200 software modules which eventually will result in two major Multics releases to other Multics sites.

In addition to the Multics activity, our IBM systems are being modified to create greater compatibility between the operating environments for the academic/research and the administrative applications. This is in anticipation of an eventual merger of these two activities on a single machine. Our choices for a new system are MVS (Multiple Virtual Systems) or VM (Virtual Machine), the latter of which is attracting the most attention from M. I. T. computer related activities which do not currently run on the campus. One of these activities is energy related and includes the New England Energy Management Information System (NEEMIS), and the other is an econometrics modeling system, TROLL, from the National Bureau of Economic Research. Some of the items still to be resolved in this very difficult decision are funding, hardware requirements, systems compatibility, impact on current users, as well as the long-term effect of selecting VM over MVS.

Another area which systems programmers have found necessary to pursue is the world of mini-computers, their operating systems, and the need to communicate now and in the future with the larger centralized facility. A PRIME 300 mini at the Sloan School originally intended as a free-standing computer resource now has communications capability and it can be used to submit work to the 370/168 in Building 39. A user group designed specifically for the mini-computer users has been established and is coordinated by Information Processing Services.

Under Multics we also support the relational data base management system, RDMS. This system originally was an experiment in the Department of Electrical Engineering and Computer Science to manage administrative data on students, faculty, researchers, and finances. Through dedicated systems programming support, it has grown to be used not only by all the Engineering departments but by many other areas as well.

WESTON J. BURNER
JOSEPH R. STEINBERG

Institute Information Services (I.I.S.)

During the past six years, the concept of the Institute Information Services has been useful in the improvement of the channels of communication among information-related offices. For the past four years, representatives of I.I.S. and other staff members across the Institute, whose responsibilities involve receiving and disseminating information, have met together in the Information Group to brief each other on current developments and to discuss common interests and tasks. This informal but continuous encouragement of more open and cooperative sharing of information across departmental lines will be especially helpful in this current period as the Institute continues to move toward making administrative services more economical and cost-effective.

The activities of the I.I.S. departments during the past year are reported below by Robert M. Byers, Director of the News Office, and Kathryn W. Lombardi, Manager of Campus Information Services.

CONSTANTINE B. SIMONIDES

NEWS OFFICE

M.I.T. again in 1976-77 commanded extensive attention in the national daily and weekly news media. The final report of the Workshop on Alternative Energy Systems, made public in a press conference in Washington, DC, and simultaneous press conferences in several foreign capitals, commanded front page attention from newspapers throughout the world. Controversy over planned recombinant DNA laboratories at Harvard and M.I.T. likewise was widely and frequently reported in newspapers and on television. A study by the Harvard-M.I.T. Joint Center for Urban Studies projecting US housing needs through 1985 received not only major news attention, but also wide and favorable editorial comment in the nation's newspapers and weekly news magazines. Two M.I.T. persons who were major news figures during the year were Professor Har Gobind Khorana, for his synthesis of the first artificial gene, and Professor Samuel C.C. Ting on the occasion of sharing the Nobel Prize in Physics for the discovery of the "J" particle. At a trivial -- and to many people offensive -- but nevertheless popularly intriguing level, a purported study of M.I.T. men's sexual habits by two women students appeared in newspapers throughout the world.

Other notable M.I.T. stories in the news were addresses presented during the World Change/World Order Lecture Series, including those by Robert S. McNamara and Willy Brandt; the appointments of Professor Frank Press as presidential science advisor, of Professor Gerald Dinneen of Lincoln Laboratory as assistant secretary of defense, and the nomination of Professor Kent Hansen to the Nuclear Regulatory Commission; the issuance of commercial records by the M.I.T. Symphony Orchestra which commanded respect and favorable comment in musical circles; exhibitions in the M.I.T. Hayden Gallery, including the widely acclaimed "Women in American Architecture" exhibit. In the area of energy, other stories that made headlines were developments in solar energy hardware, a tenfold and later another twofold improvement in the ability of M.I.T.'s ALACATOR A to contain plasma preparatory to achievement of controlled fusion, projections of natural gas markets and supplies, analyses

of national and regional energy programs and policies. One oil related story that commanded considerable attention was a finding by M.I.T. Sea Grant personnel that oil spilled from ships sunk by Nazi submarines off the coasts of North Carolina in World War II has had no lasting effect on the ocean or the shore there.

On a more routine basis, M.I.T. also continued to be in the national news week in and week out, predominately with stories about research results ranging from physics and biology to economics and political science. A sampling, but by no means a complete list, includes results from two separate M.I.T. experiments carried to Mars aboard the Viking lander, discoveries about X-ray emissions from all parts of the heavens by the M.I.T. -designed SAS-3 satellite, radio telescope observations of Venus indicating the possibility of lava flows there, new methods for testing the purity of gold, methods of detecting cancer of the breast through microwave emissions, development of an apparently economical method of treating sewage by electron beam irradiation, development of materials for artificial tendons, advances in understanding the behavior of liquid natural gas, and the success of a woman student, Sue Kayton, 19, of Santa Monica, California, in winning the annual mechanical engineering student design contest with a pulling device called the "Tugger Mugger."

All told, the national news wires handled -- and the nation's newspapers used, to one degree or another -- some 75 different story subjects out of M.I.T. during the year, up from about 60 the previous year. M.I.T. continues to enjoy frequent national attention through the established news media.

Despite the increasing volume of news of regional or national import, however, the M.I.T. News Office again this year operated under conditions of austerity that have characterized most of the Institute's administrative operations for the past several years. By careful, thorough, painful selection, we were able to reduce total press releases issued to 336, down more than 100 from the previous year. Tech Talk, the official M.I.T. newspaper published by the News Office, was reduced to 41 issues, instead of a planned 45, with a total of 332 pages of news, coming events, and classified ads. Issues were deleted selectively during vacation periods in February, March, April, and June in order to achieve economies. M.I.T. Observer was issued four times with a total of 74 pages. Reports on Research, which has a fixed publication schedule and format, came out nine times as planned, each issue with four pages. Unlike previous years, new efforts were made this year to achieve national news media publicity for articles appearing in Reports on Research and the results have been gratifying.

Staff changes during the year included the promotion of Katharine Childs Jones from the biweekly staff to the administrative staff as Assistant Director of the News Office, with special responsibility for publicizing Institute activities in the area of art, music, and culture plus regular feature reporting for Tech Talk. William T. Struble, Assistant Director, continued to be responsible for the School of Science and its related centers and to hold overall responsibility for Reports on Research. Charles H. Ball, Assistant Director, continued his responsibilities for news service for the Schools of Management, Humanities and Social Science, and Architecture and Planning, while Robert C. Di Iorio, Assistant Director, continued to be responsible for the School of Engineering. Once again, recognition must be given to Joanne Miller, Assistant Director in charge of Tech Talk for her continued effective handling of that publication in the face of continuing reductions in resources. Calvin Campbell, Assistant Director (Photojournalist), provided a steady supply of new and imaginative photographs from the campus, many of which received regional and national publication, through frequent use by the wire services.

On the biweekly staff, resignations included Katharine Zwerin, Secretary, and Susan Walker, Editorial Secretary. Ms. Zwerin was succeeded by Sheila A. Richards as Secretary and Ms. Walker was succeeded by Joan Kougasian. Ms. Walker left to relocate in Connecticut.

During her tenure of nearly five years, she handled Institute Calendar and classified ads with unusual attention to detail and accuracy for which we were grateful. Also new to the biweekly staff this year is Elizabeth Van Horn, Editorial Secretary, in charge of press release issuance. Cathryn Chadwick, who had held that position, became Editorial Assistant during the year, following Ms. Jones's promotion. Ms. Chadwick contributes importantly in reporting and writing for Tech Talk, and, as collateral duty, has made important contributions to hometown news stories about M.I.T. students -- their admission, their graduation, and their honors. Hometowning continues to be a source of concern, however, because of our inability to devote needed resources to it.

The News Office this year made use of four temporary science writers: Karen Lauterbach, and H. Paris Burstyn, science interns from Boston University; Paul M. Raeburn, a 1972 graduate of M.I.T. in physics; and Michael Brill, until recently a postdoctoral research affiliate in the Department of Biology. This a practice we hope to continue in order to give experience and practice to young people seeking to make journalistic careers in the areas of science and technology.

ROBERT M. BYERS

CAMPUS INFORMATION SERVICES

The past year has seen an increased demand for the services of all of the offices within the Campus Information Services: for assistance with design and production of publications, editorial and production coordination of catalogues and other major Institute reports, coordination of conferences and special events, advice and information on Institute activities and programs for visitors as well as for members of the M.I.T. community, and assistance to members of our international community regarding their sojourns in this country. The continued close working relations among the various offices responsible for these services has enabled them to meet these increased demands with a spirit of creativity and efficiency at a time of restricted financial and human resources.

A major change in the organization of the Campus Information Services this year was the consolidation of the Registry of Guests with the Information Center, under the overall supervision of the Center's director, Mary Morrissey.

This year also marks the inclusion in this report of the activities of the M.I.T. Historical Collections -- the Institute's window on its past. Established several years ago as an outgrowth of activities surrounding the inauguration of President Wiesner, the Collections operated as a part of the Campus Information Services this year while decisions regarding a more permanent "home" were being made. Beginning with the coming academic year, the Collections will become a part of the library system, working closely with the Institute Archives.

In the following pages are the reports of each of the organizations within the Campus Information Services: Design Services, the Information Center, the M.I.T. Bulletin, and the M.I.T. Historical Collections.

Design Services

In 1976-77 the Office of Design Services, under the direction of Jacqueline S. Casey, undertook 297 graphic design and publishing projects consisting of 515 parts.

Of these publications, 14 were in support of M.I.T.'s Leadership Campaign, 45 were Alumni Association communications, and the rest were assignments from many individual offices and departments around the Institute. Major additions to the projects undertaken by the Office this year were those related to the growing number of conferences and special events taking place on campus. As a member of the working group on conferences coordinated by Miss Morrissey, Ms. Casey provides advice on publications requirements and coordinates the design and production of all publications needed by conference sponsors.

In June 1976, David Colley, who had been the graphic designer for all Alumni Association publications, left the Institute to assume a teaching position at Ohio State University. Subsequently, Nancy Pokross was asked to assume responsibility as graphic designer for the Alumni Association. She continues to oversee the design and production of all Campaign publications with the assistance of Elizabeth Hacker, who joined the staff in July 1976 as a graphic designer. In March 1977, Gail Zimmermann joined the office staff as a production assistant, replacing Janet Brown, who has taken another position at the Institute. Production assistance continues to be provided as well by Elizabeth Ferry, production manager, and Joan Gale, production assistant.

During the past year the work of Design Services was exhibited in Fukuoka, Japan; the Kunstgewerbemuseum in Zurich, Switzerland; the University of Cincinnati; and M.I.T.'s Building 7 Corridor. The work of Ms. Casey was included in Graphis Posters 77 and Print Casebooks 2. She was the chairwoman of the design committee for the Council for the Advancement and Support of Education (CASE) Annual Awards, as well as juror for the 50th anniversary of the Society of Typographic Arts in Chicago, and the Mead Library of Ideas 21st Annual Report Competition in New York. She continues as a panelist reviewing government graphics for the National Endowment for the Arts in Washington. During the past year, Hayden Corridor Gallery featured the collages of Ralph Coburn. Nancy Pokross taught a senior independent study program at Simmons College and also served as a judge for the CASE Annual Awards. For her design of the Science School's Campaign booklet and for several Alumni Association publications, Ms. Pokross received an exceptional achievement award and three citations in the CASE "Visual Design in Print" category. Elizabeth Hacker was represented in the Boston Art Directors Exhibition and the New York Art Directors Show.

Information Center

In the past year, the Information Center, under the direction of Miss Morrissey, has continued its high level of commitment and continuing service to the visitor and the M.I.T. community at large. Although the basic purpose of the Center remains unchanged, several new ideas and programs are being developed.

As a source for reference, directions, and information on various meetings and other activities, the Center has grown into areas that serve the audience with more efficiency and skill. For example, the centralized calendar of events has become invaluable to various offices and individuals within the community who wish to plan institutional events and programs and is a useful reference for avoiding scheduling conflicts.

This year there were approximately 3,600 people taking general tours of the campus and another 800 taking specially arranged tours. Visitors still maintain a certain expectation that an M.I.T. tour will parallel a visit to the Museum of Science. The Center hopes to meet

this expectation, in part, by establishing an ongoing exhibition area with the cooperation of various departments. Of the 4,400 visitors taking campus tours this year, 1,900 were prospective students, 600 were international visitors, and 1,900 were general visitors (often members of a prospective student's family).

The publication "A Walk Around M.I. T." continues to be a popular guide for visitors (and members of the M.I. T. community) who like a more leisurely walk around the campus on their own. (Approximately 4,700 copies of the publication were given out during the year.)

In addition to answering inquiries in person, through the mail, and over the phone, the Center continues to distribute a large number of Institute publications to visitors and to members of the M.I. T. community. Listed below are some general figures on distribution of reports, publications, and notices from the Information Center:

Bulletin issues	17,302
Reports	12,372
Maps and guides	31,947
Other publications	26,645

During the past summer, the Center's staff was augmented by a visitor's booth staffed by M.I. T. students who handled over 6,000 general and academic inquiries. In June, one student, Margot Tsakonas, worked full time operating the booth and conducting tours of the campus. During July and August, two full-time students, Ms. Tsakonas plus Allan Pressier in July and John Elliott in August, were kept busy answering questions from prospective students, visitors, and the M.I. T. community, in addition to conducting campus tours. Students were also employed during the academic year as guides and office assistants. Despite the discontinuation of the Center's Sunday and holiday service, a total of 39 students were employed by the Center during the past year.

A major development this past year has been the reorganization and consolidation of the Registry of Guests with the Information Center. The Registry functions within the Center are carried out under the administration of Virginia Lyons, Assistant for International Visitors.

Foreign staff and faculty increased to 682 from 565 during academic year 1976-77, with foreign staff and faculty now constituting more than 20 percent of the academic staff. Visits by a total of 661 visitors from 64 countries were arranged by the Center.

Fourteen petitions for immigration were filed with the Immigration and Naturalization Service during the past year. A number of significant changes in Federal and state law effective in January 1977 have increased the complexity of the cases handled by this office. This year, the office cosponsored (with the Foreign Student Office) a workshop to familiarize foreign students with immigration laws and procedures that may apply to them after they have received their degrees and wish to work in the US either temporarily or permanently. It was decided to make this a semi-annual event. In addition, plans are being made to acquaint administrative officers and department heads during next academic year with the various problems involved in filing petitions for permanent residence cases owing to the increasing complexity in the law.

This past spring the Center coordinated a program with the Committee on Scholarly Communication with the People's Republic of China to sponsor a delegation from that country for a two-day visit with the Departments of Chemistry and Materials Science and Engineering.

During the year, 19 alumni and faculty members were chosen to represent M.I. T. at inaugural functions. Formal "greetings" were sent to three institutions -- Tufts University, the Université Catholique de Louvain, and Brown University.

In addition to supervising the work of the Center, the Director has major responsibility for coordinating many of the special events on campus, including the annual Killian Award Lectures, Commencement (as Executive Secretary of the Committee on Commencement), and major conferences and symposia. As a member of the Facilities Use Committee (which is responsible for determining whether to allow use of M. I. T. facilities by groups outside the M. I. T. community), Miss Morrissey acts as coordinator of a working group which assists in the planning and operation of major conferences and events at the Institute. The creation of this service has cut by an impressive 70 percent the amount of time sponsors previously had to spend in setting up conferences.

The Director once again noted the spirit and cooperation of all of the members of the Information Center staff: Virginia Lyons, Kathleen Barrett, Terri Priest, and Brenda Loew.

M. I. T. Bulletin

Publication of the M. I. T. Bulletin continues to be managed by Janet L. Snover, who once again has produced the Bulletin issues in the most cost-effective manner without sacrificing the quality of the publications. Fiscal year 1977 production costs for all issues of the Bulletin were 22 percent (or \$30,000) lower than in fiscal 1976. Yet the quality of the finished products remains high. The 1976-77 issue of Courses and Degree Programs received the first place award for excellence in typographic design, layout, readability, and clarity from the National Composition Association, a section of Printing Industries of America.

During the upcoming year, the Editor of the Bulletin will explore the possibility of further economy and greater effectiveness by combining the General Catalogue and Courses and Degree Programs into one book; this would provide a complete picture of the Institute to registered as well as to prospective students.

In its current format, the General Catalogue presents information on campus activities, housing, and an abbreviated discussion of the academic program. The General Catalogue is directed toward the information needs of prospective students. Courses and Degrees, on the other hand, is prepared for use by current M. I. T. students, and contains detailed academic information including departmental curricula and subject descriptions. Recently, however, there has been an increasing number of prospective students requesting both catalogues because they want to review the detailed academic information as well as the general academic information and the material on housing and campus activities. Therefore, the most efficient and economical way of informing our prospective students may be to combine the two catalogues. This matter will be brought before the Committee on Educational Policy for discussion in the fall.

This year, the format of the small Report of the Treasurer was changed in order to make the document more easily read by the general audience. This smaller version became one of the issues of the Bulletin, replacing the larger, more comprehensive report which is published later in the year. There are currently five issues of the Bulletin: The Report of the President and the Chancellor, The Report of the Treasurer, The General Catalogue, Courses and Degree Programs, and the Summer Session Catalogue. Recent changes in the second-class postal regulations now guarantee that college catalogues may be mailed at second-class rates and reduce the minimum number of issues in a Bulletin series to four. If the catalogues are recombined next year some additional changes in the composition of the Bulletin series may also be made at that time.

In August, Susan Shansky was hired as the Production Assistant for the Bulletin. Her efficiency and thoroughness have helped immeasurably in the production of the Bulletin issues. In addition, she edited and proofread the Special Summer Session brochures, a service which will continue in the Bulletin office.

In the spring, Ms. Snover, the Editor and Production Manager of the Bulletin, was selected as vice president of the New England College Editors Association. In this capacity she will help organize workshops on editing and production of college publications.

Historical Collections

The M.I.T. Historical Collections, under the direction of Warren A. Seamans, marks its first appearance in the Report of the President and the Chancellor with this writing. It would seem logical to begin with a synopsis of the Collection's history.

An effort in 1971 -- to create an historical exhibit as part of the inauguration activities for President Wiesner -- gave birth to the M.I.T. Historical Collections. The search for appropriate materials led to more and more discoveries related to the history of the Institute. As they were uncovered, these materials were integrated into a unified but many-faceted research facility which now houses an extensive photographic collection (estimated at 500,000), portraits (131 works), scientific instruments including working models and prototypes (1,200 pieces), films (325 cans), student architectural drawings (12,000+), tapes, extensive biographical materials, and memorabilia.

From a small room in the General Radio Building (later known as the EPSCO Building) at 265 Massachusetts Avenue, the facilities have expanded to 12,000 square feet.

In June 1973, Warren Seamans was appointed full-time Director of Historical Collections. Walt C. Taylor, co-founder with Warren Seamans, serves gratis as Consulting Curator. The staff includes two full-time and one part-time assistant: Barbara Linden who handles internal systems and administrative matters, Marcia Conroy who deals with incoming requests for information, and Joan Loria who works part-time creating and constructing exhibits. Several students, from M.I.T. and Northeastern University, work on cataloguing and special projects. Several volunteers have also assisted at the Collections.

M.I.T. Historical Collections now serves as the Institute's museum and is organized to answer expeditiously the questions of researchers. The past year has been marked by significantly increased activity in many areas and by several substantial accomplishments.

Photographic and Biographic Collection. A concentrated and productive effort has been made to catalogue the materials in this collection. Considerably more than one-half of the photograph collection is now fully catalogued, with the remaining portion organized for ongoing numbering and cataloguing work. In each of the last four years, use of this collection has more than doubled; the Collections now has an average of more than 60 requests for photos and/or biographical information each week.

As the existence of this collection becomes better known, additions to it multiply. The largest and most important single acquisition of the past year was the approximately 25,000 photos which comprised the Radiation Laboratory collection. These had been in dead storage in Pennsylvania since the end of World War II and are already finding wide usage.

Two volunteers made outstanding contributions this year. Walter C. Woodman, Class of 1925, has cross-referenced Technology Review into our central files, and has, thus far, progressed from 1899 through 1950. Leona Riskin, wife of Archie Riskin, Class of 1932, has canvassed for new acquisitions. Through her efforts, significant materials have been obtained relating to Elihu Thomson, Robert Van de Graaff, Clair Turner, Bernard Proctor, Robert Bigelow, and Richard Maclaurin, among others.

Several other notable collections of material have also come in. These include the papers and memorabilia of Dugald Jackson and the papers of Lois Lilly Howe, Class of 1890, the first woman to establish an architectural firm, as well as materials from her later firm of Howe, Manning and Almy (Eleanor Manning O'Connor was Class of 1906 and Mary Almy was Class of 1920).

Film Collection. A catalogue of approximately 75 films has been completed, and cross-indexing has begun. Circulation copies of most of the important and/or entertaining films are available for use by interested parties and the demand for these films is increasing.

Using this collection in work on an Undergraduate Research Opportunities Program project, David R. Karp, Class of 1978, has compiled a film history of M. I. T. A version of this was shown at the Alumni Officers Conference banquet in September and has also been shown at the reunions of the Classes of 1917, 1918, and 1927, and to the Honorary Matrons and Professors Emeriti. In addition, numerous alumni gatherings around the country have viewed the film, including the Cape Cod M. I. T. Club and six showings at the Florida Alumni Clubs.

Materials from this collection were used this past year by J. Scott Ferguson, Class of 1978, in a special historical program entitled "Eye on the Past" which was broadcast on the Institute's television channel. The series is being repeated this summer.

Architectural Drawings Collection. Interest in the student architectural drawings showed a marked increase; the number of requests has doubled over the previous year. Photos of drawings from the collection appeared in at least four books published during the year. Fifteen drawings were in an exhibition entitled "Women in American Architecture" mounted by the Archive of Women in Architecture at the Brooklyn Museum in February. This exhibit came to Hayden Gallery for six weeks during May and June. Requests also have been received from several other museums for loans of drawings. Plans are now being made for a United States Information Agency tour of Europe which will include five M. I. T. student drawings.

Although the restoration portion of the project is not yet complete, significant progress has been made in converting the two catalogues of drawings and theses into a computerized catalogue. This will provide for several methods of retrieval not available at this time. This work has been done in close cooperation with the Information Processing Services.

An article written by Warren Seamans and published in the winter 1976 issue of Technology and Conservation explains the process used in restoring and preserving these architectural drawings; it has received wide distribution and numerous requests for additional assistance.

Instrument Collection. A continuous flow of fascinating and noteworthy instruments has come in during the year. The most important acquisitions were more than 120 Radiation Laboratory instruments from various sources and a superb collection of 80 antique meters, motors, and generators from Ellsworth Wente of Hamilton, Ohio.

A British Broadcasting Corporation television production on Alexander Graham Bell was filmed, in part, at our facilities, utilizing the unique operational Blake transmitter exhibit as the central attraction. The Blake instruments were a gift of John Drisko, Class of 1927. In addition, instruments have been loaned to the Boston Museum of Science, the Smithsonian Institution, and several trade expositions.

An excellent collection of inertial guidance instruments and supporting documentation is also being assembled in cooperation with Draper Laboratory. All historical material related

to the Instrumentation Laboratory/Charles Stark Draper Laboratory, Inc. is being formed into a Charles Stark Draper Laboratory Historical Collection. Gilbert M. Herrett, a 25-year Draper employee, serves as their coordinator.

Exhibits Program. Another facet of the Collections' work has been the exhibits program under which 23 exhibits using Historical Collections materials were designed and constructed. The largest of these was done in cooperation with the Center for Space Research and was shown at Cape Kennedy during the United States Bicentennial Exposition on Space and Technology. Nearly a million people visited this exhibition during summer, 1976. The show was recreated in its original form in Kresge Auditorium lobby for the Corporation Development Committee meeting in November. The photographic sections were then reconstructed into an exhibit for the main corridor.

Also created for exhibit in the main corridor during the Bicentennial was an exhibit entitled "Spirit of '76" which depicted the Institute as it was a century ago. A smaller traveling version of this show has toured to alumni clubs around the country.

As part of the reunion of the Radiation Laboratory, a major exhibit of 150 photographs as well as hardware was mounted in Kresge. This, too, was recreated for an extended life in the main corridor, while the models and hardware have been transformed into a separate exhibit within the Collections' facilities.

In cooperation with Draper Laboratory, a large photographic show entitled "Charles Stark Draper -- Images of the Man," along with several very specialized hardware exhibits designed by Vincent J. Paolino, Class of 1978, were prepared for that Laboratory's Family Day. These will remain as continuing exhibits in their new building.

Five separate exhibits were prepared for Technology Day and Reunion Week activities. These included a photographic perspective of the work of Professor Harold "Doc" Edgerton, Class of 1927, which will also reappear in future use, and a restructuring of the Sea Grant exhibit. Although the latter was revised especially for Technology Day, this exhibit will now travel extensively.

Smaller shows were mounted on campus for special events such as Women's Career Day and Employees' Open House. Permanent displays were also prepared for the New York Alumni Reception Center and for Dewey Library.

Museum Functions. Sixteen special activities brought more than 1,600 people to Historical Collections during this past year. Seven major functions were held during Reunion Week: two dinner dances, two buffet dinners, two brunches, and one breakfast. Other groups, including the Association of M. I. T. Alumnae, the Boston Stein Club, the Boston Alumni Club, the Wellesley Exchange Committee, and the Committee for Architectural Records in Massachusetts, have held meetings and conferences in the Collections' facilities.

In addition to the steady flow of researchers, there has been a significant increase in the number of casual visitors who have found the Collections.

This past June saw the graduation of the Collections' Northeastern University Cooperative students, Michael W. Yeates and Joyce E. Bedi. Mr. Yeates worked for more than three years and Ms. Bedi for a year and a half. Their contributions to every facet of the operation have been outstanding.

KATHRYN W. LOMBARDI

M.I.T. Press

Publishing operations and financial conditions of the M. I. T. Press continued to improve in fiscal year 1977. Sales were higher by 4 percent over the previous year. Interest payments on our working capital debt were lower than anticipated, and the total debt to the Institute was reduced by \$172,000 during the year. Plant and manufacturing costs increased 50 percent in fiscal year 1977, reflecting a 25 percent growth in the new book list. A cash reserve of \$578,000 was retained as a result of continuing reduction in accounts receivable and a \$200,000 improvement in cash flow through direct mail selling. Our operating statement reported a savings of \$39,000 in the planned operating deficit for the year. Our journals business has grown in the past year to more than \$500,000 per year. These positive results were not "windfalls," but the products of efforts to manage and control operations in ways which produce a basis for reliable forecasts. Much of the improvement realized in the operating plan for fiscal year 1977 will affect operations in the subsequent years.

Several areas present opportunities for us to continue to improve performance as we reach toward our goal of financial independence from the Institute. Encouraging strides continue to be made in increasing both the quantity and quality of new books. We are making further efforts to produce a comfortably large inventory of projects under contract for future publication, which will allow us to design lists for seasons with more flexibility in scheduling than has been possible in the past. We are also aiming toward increasing the acquisition rate for projects which fall into the "revisable" category; those books -- primarily texts and reference works -- must continue to grow as a percentage of our new publications. Our estimate is that by the end of fiscal year 1979 the acquisition effort will reach its ideal rate, and the impact of that effort should begin to be evident in the same year.

In our Editorial department, we will continue to provide the support that produces the excellence our audiences have come to expect from M. I. T. Press publications. At the same time, we will continue to strive to be more deliberate in distinguishing those projects which require close editorial scrutiny from those which should receive less attention. With increased developmental involvement by acquisition editors, this approach will allow us to maintain quality and at the same time control the costs of the editorial/design/production process.

We have introduced a new accountability system to better calculate profitability and discount cash flow on a title-by-title basis. These new methods allocate overhead on a variable basis to new and backlist titles. The system, which will be programmed for use by way of a video display terminal using Institute hardware, will provide an opportunity for us to make better decisions about pricing and print quantities.

Our Production and Design departments have been reorganized to better suit the needs of individual projects. New systems and personnel are in place, and the positive effects should be evident in operating costs and productivity during the coming year.

The past year's experience with the inhouse computer composition development program is presently being assessed, and long-term benefits of the installation of a dedicated system for composition are being evaluated. The opportunity to reduce composition costs by 10 to 30 percent will represent significant savings in cash and will have an even greater impact on cost of sales.

In marketing, we will continue to see better performance. While the Press enjoys perhaps the highest percentage of foreign sales of any university press (presently about 24 percent of our sales are to foreign customers), our objective within the next four years is to increase this amount to 30 percent. Domestically, we will place new emphasis on direct mail selling, which doubled in the past year and will continue to increase in dollars and as a percent of total sales. In fiscal year 1978, continuing use of market strategy and planning will focus our attention more closely on individual new titles to design marketing campaigns most precisely suited to individual books.

Individual title sales will continue to be considered in relation to the price/cost ratio through overall annual price reviews as well as on a book-by-book basis during reprint cycles. We continue to improve systems for monitoring inventory levels and values and are reducing inventory writedown requirements each year. We also hope to improve royalty ratios on the first printings of books meant for narrow scholarly markets and showing little promise of producing net income.

Fiscal 1977 was the last year of the original three-year financial plan for the Press. It was also the first year of a new five-year plan, which was presented to and approved by the senior administration and the Executive Committee of the Corporation in the spring. In general, the new plan called for continued modest funding through fiscal 1981, after which time the Press will require no direct financial support from the Institute.

In fiscal 1978 we will launch a developmental effort in cooperation with the Institute to create capital funds for support of the publishing program. The Press continues to be first and foremost a scholarly publisher, and many of our books which deserve publication will continue to lose money on a title-by-title basis. The profitability of the balance of the list, and the support by way of capital funds for publication, will provide a basis for continuing the publication of scholarly books meant for limited but important audiences.

In summary, fiscal year 1977 witnessed continuing improvement in the Press's operations across the board, and we continue to identify other areas for improvement. While the two unknowns continue to exist (future books and the fluctuating market), we are satisfied at having made the provisions to monitor and address these unknowns.

THE PUBLISHING PROGRAM

In fiscal 1977 the Press published 58 new hardcover titles and 36 new paperback titles, compared with 47 hardcovers and 28 paperbacks in the previous fiscal year. The Press also launched three new journals: Oppositions, Neurosciences Research Program Bulletin, and Journal of Law and Medicine. The table below shows the percentage breakdown of new titles published in recent years in several broad subject categories:

<u>Year</u>	<u>Social Science</u>	<u>Humanities</u>	<u>Engineering</u>	<u>Science and Mathematics</u>	<u>Art, Architecture and Urban Planning</u>
1972-73	28	14	19	27	13
1973-74	35	14	19	14	18
1974-75	32	12	12	25	19
1975-76	21	17	18	34	10
1976-77	17	15	24	25	19

Last year, the Press published 94 titles compared to 75 during fiscal 1976. A comparative distribution appears below:

Fiscal year	original + reprint = total;				simultaneous		
	hard	+ paper			hard & paper	import/distribution	
FY76	41	27	44	24	68	2	11
FY77	58	36	74	20	94	7	25
FY78*	66	32	72	26	98	1	10

*estimated

Sales statistics are as follows:

	<u>FY75</u>	<u>FY76</u>	<u>FY77</u>	<u>%Change</u> <u>FY76-77</u>
<u>SALES</u>				
Net Sales, Domestic	2,256,000	1,995,000	2,067,000	3.6%
Net Sales, Foreign	657,000	600,000	638,000	6.3%
Total Sales	\$2,913,000	\$2,595,000	\$2,705,000	4.2%

Sales during fiscal year 1977 improved and costs of sales were reduced. Inventory writedowns were significantly lower than in the previous fiscal year and were less than forecast, as a result of continuing attention to inventory control. In fact, a reduction in inventory writedown has allowed us to write off some items held in suspension for many years. Royalties were lower than anticipated, relative to sales, because of our success with the special spring sale which moved 30,000 copies of excess stock. International sales improved slightly despite the continued depression of the pound, continuing trouble with representation in Canada and India, and the impact of the short list in fiscal 1976. Operating expenses were higher because of our effort to expand the Press's capabilities and list to meet the financial objectives of the five-year plan and to support our expanded direct mail program.

ACQUISITIONS

In fiscal 1977 the Acquisitions department at the Press consisted of four full-time staff members. Arthur Evans, responsible for acquisitions in science and mathematics, completed his first year with us; as did Colin Jones, responsible for architecture, urban and regional planning, and visual arts. Barbara Ankeny continued to acquire in the social sciences, humanities, and linguistics; while Frank Satlow devoted his time to the development of the list in engineering systems and technology. Developmental planning has become an integral part of the acquisition process. Each acquisitions editor has continued periodically to review and revise the overall developmental plan for each active discipline in continuing attempts to narrow the focus of our list, to increase the advanced text and reference component, to explore the possibilities of revising successful backlist titles, and to expand series publications. Among the series plans launched last year were Energy and Energy Policy, and Systems Engineering. Proposals for the establishment of other series in Nutrition, Neurosciences, Control Systems, Cognitive Sciences, Management Sciences, and Corporate Strategy and Planning are in preparation for review and implementation during the coming fiscal year.

The Acquisitions editors presented 76 new book proposals to the Editorial Board at 13 meetings throughout the year. Of these, 72 were accepted for publication. Three were withdrawn, and one was declined. These figures compared with 80 proposals reviewed during the previous year which resulted in 76 accepted for publication, one withdrawn, and three declined. Approximately 600 unsolicited manuscripts and proposals were rejected by the editors, most without outside review. During the past year, approved proposals resulted in 83 contract signatures with authors, compared to 74 during the previous year.

In 1976-77 the Editorial Board was led for the third year by Professor Hartley Rogers, Associate Provost of M. I. T. Professors Robert M. Fano (Electrical Engineering), John G. King (Physics), and Charles Weiner (History of Science and Technology) served the second year of their three-year terms. Professors Daniel M. Holland (Management) and Walter S. Owen (Materials Science and Engineering) completed their terms; and Professors Joan Bresnan (Linguistics) and Harold J. Hanham (Dean of Humanities) served their first year. Professor Lisa Steiner (Biology) substituted for Maurice S. Fox (Biology) in the middle year of his term. Professor Stanford O. Anderson (Architecture) substituted for Henry Millon (Architecture) in the first year of the latter's term. Constantine B. Simonides (Vice President of the Institute), Frank Urbanowski (Director of the Press), and Jay Lucker (Director of the M. I. T. Libraries) serve as non-voting members of the Editorial Board.

EDITORIAL

The Editorial department has continued to draw authors' praise for refinement and editing of manuscripts. Managing Editor Helen Osborne, with editors Ed Agro, Larry Cohen, and Cynthia Ware, continue to carry the main burden of an increasing workload, and Paul Tasner joined the full-time staff in July. Full and part-time editorial assistants helped to relieve the excessive workload, as did the increasing use of freelance editorial services. During the past year, Mr. Agro spent full time on the Encyclopedic Dictionary of Mathematics, and Mr. Cohen spent half of his time on that project: a 6,000-page manuscript or 1,750 book pages. It was a remarkable editorial achievement. In all, 30,137 manuscript pages were processed last year, compared to 19,250 in fiscal 1976. Freelance editors handled 17,000 of those pages this past year, compared with 8,500 in the previous year. Other pertinent statistics appear in the chart below.

	<u># of Books</u>	<u># of Pages</u>
Mss. In-house	7	4,048
Mss. Freelance	34	17,148
Camera Copy	8	5,196
Camera + Ms.	5	3,645
 TOTAL		 30,037
 Encyclopedic Dictionary of Mathematics, In-house	 2	 6,000

The in-house staff will continue to edit the more demanding projects and to meet the needs of an increasing shift in the Press's publishing program from the social sciences toward the sciences and engineering.

DESIGN

The Design department, under the direction of Muriel Cooper, continued to maintain our high graphic standards in spite of a heavy workload. Flow of schedules was maintained with the fine freelance help of Sylvia Steiner, who rejoined the department as of July 1 in the full-time capacity of Design Manager, enabling Mario Furtado to concentrate more time on the design of marketing materials and journals and to assist with production problems. Donna Schenkel and Wendy Richmond, both new to the department this past year, have contributed with sensitivity to the design quality and productivity of the group.

Particularly noteworthy designs last year were Iyanaga, Encyclopedic Dictionary of Mathematics; Rowe, Mathematics of the Ideal Villa; Reiser, Ethics in Medicine; the revised Venturi, Learning From Las Vegas. Taylor, Human Reproduction represented an exciting first as an outstanding example of a multivolume text slide package. Davis, The New Television represented an innovative graphic configuration of aural transcription and images. The two latter projects were included in last year's AIGA 50 Books Show. Two art books designed and produced outside the Press won awards in the New England Book Show for excellence in design: Kranz, Early Form Sequences and Smithsonian, Images of an Era.

On July 1, Muriel Cooper became Special Media Projects Director at the Press and Associate Professor in the M. I. T. Department of Architecture. In her dual role she will explore possibilities of publication and cooperative projects relevant to the Press, the Visible Language Workshop, and other departments at the Institute. She will continue to act as a design consultant on special projects at the Press.

Mildene Bradley assumed the responsibility for the off-site computer composition program under the supervision of Ms. Cooper, and worked closely with the Editorial department in a one-year feasibility study of in-house composition. Books produced in the program were more easily handled by the Editorial department because of fine quality control procedures, and our schedules benefited as well. Approximately 40 books were produced during the year using the program. An assessment of this experience is now under way to determine the level of savings in composition costs with a full on-site system.

PRODUCTION

During the year, the Production department supervised the production of 48 new titles, 19 new paperback reprints, 7 rebinds, and 26 journal issues. The department consisted of Production Manager Patricia Mahon, assisted by Lee Ewing, Elizabeth Whitney, and Robin Grossman. Ms. Mahon, who has been responsible for the consolidation of the Production function into an efficient operation, left in June to direct Boston University's publications, and we were disappointed to lose her. Our new Production Manager Richard Woelflein brings his thorough knowledge and extensive experience to us and promises to continue ensuring high levels of performance in production.

The Production department continued to exert efforts to find alternative methods of composition and manufacture at less cost and constant quality. In the continuing effort to print conservatively, the department must be credited with the special attempt it makes to economize on increasing short-run production.

MARKETING

During the last year, completed marketing studies resulted in a reorganization of the Marketing department and the formulation of a significantly different approach to promotion and sales, with increasing emphasis on direct mail sales. In fact, sales continued to improve, and new hardcover sales in terms of unit per dollar and dollars per title were approximately 10 percent higher than in the previous year. Direct mail income doubled as a percentage of total sales. The table below indicates our sales by customer type:

<u>Customer Type</u>	<u>FY74</u>	<u>FY75</u>	<u>FY76</u>	<u>FY77</u>
Government	(10,851)	22,394	27,937	25,355
College Bookstore	373,279	441,215	479,110	467,091
Retail Bookstore	376,140	457,775	541,702	482,299
Wholesaler and Jobber	262,080	408,027	380,149	368,804
Public Library	3,276	18,050	26,892	18,150
College and University Library	70,510	150,165	158,345	161,758
Business	1,781	36,719	53,190	61,008
Institute	1,559	2,970	9,379	5,614
Direct Mail	50,870	459,464	195,253	393,352
TOTALS	1,422,151*	2,192,178*	1,905,636*	2,002,483*

* Totals include all domestic sales, some of which are not tabulated in the above categories.

The Marketing department has been reorganized into two separate divisions: one concerned with sales and overall marketing under the direction of Tom McCorkle, and a new Promotion department under Brooke Stevens. The most significant changes will be evident in the Promotion department with the creation of a direct mail selling program based on eight subject-matter catalogues to be revised twice each year, rather than the individual book brochures which have proved too costly relative to income production. Major marketing goals are to double direct mail income during the coming years and to increase foreign sales by 25 percent over previous years.

Ms. Stevens, with the assistance of Mary Aldridge, produced 44 brochures for 30 separate mailings to 300,000 people, accounting for the sale of 5,500 new book units. In a large general sale, "The M. I. T. Press Book Clearing," a brochure was sent to 250,000 individuals and resulted in 33,000 units sold; and a special Christmas catalogue sent to 5,500 individuals resulted in 2,000 units sold during the year. Randall Goff was responsible for three subject area catalogues (Linguistics, Architecture, and Energy) which were mailed to 100,000 people and resulted in 6,000 units sold. In all, 785,000 mailing pieces resulted in 50,000 books sold.

Mr. Goff was also responsible for placing 103 advertisements which appeared in major media (including the New York Times, New York Review of Books, Scientific American, and Washington Monthly Report) and professional and scholarly journals (including American Scientist, Urban Affairs Quarterly, Journal of the American Statistical Association, AIAA Journal, Neuroscience, and The American Political Science Review). In addition, he was responsible for two seasonal announcement catalogues, each of which was sent to 30,000 libraries, bookstores, book reviewers, and selected faculties throughout the United States and abroad.

In publicity, new books were matched with appropriate periodicals and newspapers and about 900 reviews were received in major popular and specialized media including the London Times Literary Supplement, the Sunday New York Times, The New York Review of Books, Science, and Nature. Books receiving particularly strong media attention during the year included Hoffman, History of the German Resistance, Rowe, Mathematics of the Ideal Villa, Hayden, Seven American Utopias, and Lynch, Managing the Sense of a Region.

Emily Rosenthal made arrangements for Press representation at exhibits, including 18 attended by personnel from the Press and 94 combined exhibits with other university presses. She was also responsible for all text promotion, through 55,000 brochures mailed to solicit text adoptions. This mailing resulted in free examination copies sent to 3,000 interested instructors and desk copies of adopted books to 2,300. Books eliciting significant text interest were Flink, The Car Culture, Lynch, Managing the Sense of a Region, DeNeufville, Airport Systems Planning, Pacey, The Maze of Ingenuity, Rowe, Mathematics of the Ideal Villa, Dietz, Dwelling House Construction. Older titles continue to be widely used in classrooms: Rasmussen, Experiencing

Architecture, Luria, 36 Lectures in Biology, Akmajian and Heny, Principles of Transformational Syntax, Lynch, Site Planning and the Image of the City, Beck, Hematology, Bishop, Discrete Multivariate Analysis, and Chomsky, Aspects of the Theory of Syntax.

Don Stanford supervised our growing international sales program. The chart below compares international sales over the last three years.

	<u>FY75</u>	<u>FY76</u>	<u>FY77</u>
Canada	85,000	65,000	85,000
Far East and South America	111,000	148,000	158,000
Australia and New Zealand	20,000	(28,000)	25,000
London	<u>441,000</u>	<u>415,000</u>	<u>370,000</u>
TOTAL	657,000	600,000	638,000

In addition, Mr. Stanford arranged for the translation of 12 books into foreign languages (compared with 23 in fiscal 1976) and the sale of seven titles to book clubs, including Hoffmann, History of the German Resistance (13,000 copies) and Lynch, Managing the Sense of a Region (4,500 copies). Peter Talbert-Hall continued to represent the Press in the eastern United States and eastern Canada. We share the services of David Blick with Harvard University Press in Midwest representation; and of Judy Kucera with Harvard, Yale, and Princeton University presses in the western United States, western Canada, Alaska, and Hawaii.

JOURNALS

The Journals department is treated internally as a separate division of the Press and all expenses are expected to be met directly by journal revenue. Journals provide a vehicle for keeping the Press visible in important disciplines and for bringing M.I.T. Press books to the attention of interested audiences. Opportunities can also be provided for book projects to emerge from editorial dynamics of the journals.

The Press continued to publish Linguistic Inquiry, The Journal of Interdisciplinary History, and Cell, producing a net income for the first time. Fiscal 1977 witnessed the first full year of publication of the new journal Oppositions, and the launching of new journals: Neurosciences Research Program Bulletin and the American Journal of Law and Medicine. New journals are expensive to launch, but benefits should accrue next year, and all three should at least break even financially.

Cell, a monthly journal of molecular biology, currently has a subscriber list of about 1,700. The journal continues to claim an exceptionally high renewal rate, despite a substantial price increase. Cell reported its first profitable year in fiscal 1977.

Linguistic Inquiry is also a profitable member of the Journals list; the number of subscribers has reached 2,500. The first volume in the related monograph series sold out, and more monographs are planned for the coming years.

The Journal of Interdisciplinary History enters its eighth year of publication with 1,500 subscribers.

Oppositions, a journal of criticism in architecture, was selected in March of this year by the American Association of Publishers as the outstanding journal in the technical, scientific, and medical division. Oppositions has required considerable investment to launch, and reported a substantial deficit this year. Subscriptions continue to increase, however, and with the implementation of new cost controls, we fully expect Oppositions to break even this coming fiscal year and to begin producing profit in fiscal year 1979.

The Neurosciences Research Program Bulletin was acquired in January, and the first direct mail campaign is planned for September 1977.

The American Journal of Law and Medicine, also acquired during this past year, is just beginning to show positive response and build-up of subscribers. To date there are 2,100 subscribers, and we expect that the subscriber list will double during the next two years, putting this journal in the black for the first time.

FINANCIAL DEPARTMENT

The Financial department is responsible for financial, business, and fulfillment systems including management of inventory, warehousing and shipping operations, credit and collections, and the entire order fulfillment cycle. All segments of the operation have improved noticeably under Financial Manager Michael Leonard's leadership. With the careful attention of Richard Salmon, Credit Manager, accounts receivable were reduced from \$501,000 to \$466,000 during fiscal year 1977. Most outstanding large accounts were settled, comparative aging of accounts improved, and foreign accounts receivable were substantially reduced. Cornelius Kiely, Accounting Manager, continued to provide firm control over a variety of financial transactions at the Press. The year saw a continuation of monthly interim reporting on operating performances, and of techniques which continue to improve predictability of inventory writedowns and manufacturing costs. Barbara Saulenas, Order Fulfillment Manager, continued to keep that complex process working efficiently. Noteworthy was the completion of our first year in a new warehouse, UNISERV, which has succeeded in providing better service to customers and cost savings to us.

UNISERV has provided us with an opportunity for better customer service and a reduction in fulfillment costs. In addition, a new electronic data processing system, Ultimacc, is scheduled for installation during the next year. It promises to cut electronic data processing costs by 30 to 40 percent beginning in fiscal 1979.

As mentioned above, the assets of the Press continue to harden in line with policies for control over inventory and accounts receivable. Cash flow is positive, thereby enabling reduction in the debt to the Institute and protecting the Press's cash reserve in anticipation of an increase in publishing load during fiscal years 1978 and 1979.

The M. I. T. Press Management Board, which serves as a Board of Directors for the Press within the Institute structure, met twice last year in full session to review our operations. Serving on the Management Board in fiscal 1977 were: Professor John Deutch (Chemistry); Richard B. Gladstone (Senior Vice President, Houghton Mifflin Company); Professor Myron Weiner (Political Science); Associate Provost Rogers; Jack Schulman (Director, Cambridge University Press); and W. Bradford Wiley (Chairman of the Board, John Wiley & Sons). Constantine B. Simonides, Vice President, is Chairman of the Management Board.

FRANK URBANOWSKI

Plasma Fusion Center

The energy crisis, alleged or real, has led to a great interest in applied research in a variety of heretofore almost neglected fields. These include solar heating, solar electric power, wind energy, bio-material conversion to methane, and controlled nuclear fusion.

Until now, controlled fusion has been looked upon as a technological curiosity with possible payoffs in the 75- to 100-year time span. Recent interest in increasing our possible fuels from other than fossil sources has enhanced research support for the so-called inexhaustible fuels, such as solar and fusion. In particular, recent experimental results in plasma fusion research have given us a much more optimistic feeling about the period in which plasma fusion can start to be available as a real energy source. This period is now thought to be 25 to 40 years, which makes the long-range economics much more interesting.

M. I. T. has long had a group working in basic research of plasma physics starting under Professors William Allis and Sanborn Brown in the pre-World War II time frame. In addition to work in the Department of Physics, interest expanded in the 1960s and 1970s into many other departments and laboratories of the Institute.

In the 1960s USSR physicists, especially academician Artzimovich, developed the so-called Tokamak approach to high-temperature plasmas which are contained by toroidal magnetic fields. In 1969, Professor Bruno Coppi of the Department of Physics suggested the use of the very high magnetic fields available through the Bitter technology used by the National Magnet Laboratory (N. M. L.) of M. I. T. He was joined enthusiastically by many members of the Research Laboratory of Electronics (R. L. E.), and in particular by Professor Benjamin Lax, Director of N. M. L. This work culminated in the design and construction of a Tokamak device called Alcator, an Italian (or Latin) acronym for a high-field toroid. Briefly, for "practical" fusion to take place, very high temperatures of the order of 50 million °K are necessary. In addition, one must have a reasonably high concentration of the ions forming the plasma, and a period of about a second for the concentration and temperature to be simultaneously achieved.

M. I. T.'s Alcator has been very successful in carrying these three critical numbers -- temperature, concentration, and time duration -- to higher values, in particular concentration and duration are getting closer to the critical numbers known as the Lawson conditions. Our successes with the initial Alcator have led to the funding of Alcator C, now expected to be completed by January 1979, and a much stronger interest by the Energy Research and Development Administration (ERDA) in our entire plasma fusion program.

The Plasma Fusion Center was established in September 1976, "to serve as an intellectual and administrative focal point for work in plasma physics and in fusion." The work of the Center is strongly supported and very interactive with the Departments of Physics, Electrical Engineering and Computer Science, and Nuclear Engineering, and also with the Magnet Laboratory and R. L. E. We are now funded by ERDA through two grants: one for basic and applied research in plasma physics, and one for confinement systems (applied fusion research). Recently an additional task, to develop superconducting materials for very high magnetic fields, was undertaken under the first grant. This latter task is being carried out by Professors Robert M. Rose in the Department of Materials Science and Engineering, Margaret MacVicar in the Department of Physics, and Drs. Brian Schwartz and Simon Foner in the Magnet Laboratory.

Faculty involved in the general research studies include Professors Coppi, Abraham Bers, George Bekefi, Thomas Dupree, Lawrence Lidsky, J.J. Gerald McCune, Joel Moses, Peter A. Politzer, Louis D. Smullin, and James T. Woo, and now Professor Miklos Porkolab who joins the Department of Physics officially on July 1. Personnel involved in confinement systems include Professor Ronald R. Parker of Electrical Engineering and Computer Science, in general charge of the experimental program, Professor Coppi, and Drs. Daniel Cohn, D. Bruce Montgomery, Awinash Gondhalekar, and David Overskei of the N. M. L. Dr. Meyer and George Petievich assist the Director on technical and administrative aspects of the Center's work.

An important event of the past year has been the achievement with Alcator A of a concentration-time product of more than 2×10^{13} ions sec/cm^3 . This is within a factor of 5 of the Lawson condition. It is believed that with careful attention to the cleanliness of the plasma and to the proper pulsing of greater magnetic fields (of the order 150,000 gauss) that it is possible to achieve the Lawson criterion of 10^{14} secs/cc. This is of course the design criterion for Alcator C.

In order to achieve the appropriate temperatures of 6 to 10 times our present plasma temperature, it will be necessary to bring in additional heating by means of neutral beams or by means of radio frequency power. We are collaborating with the Lawrence Berkeley Laboratory and with the Oak Ridge National Laboratory on the neutral beams work. Professor Bers on the theoretical side, and Professor Porkolab on the experimental side, are working on the development of radio frequency heating processes. It is our hope that Alcator A can be adapted in the near future to introduce radio frequency heating tests. Alcator C is able to accept both types of heating.

In addition to our main device, Alcator, we have always had small devices for experimental and teaching programs. The highlight of the past year has been the completion, in Professor Bekefi's laboratory, of Versator II which will be very useful in the radio frequency heating program as well as being a major asset to the development of diagnostic techniques.

All of us in the plasma community are looking forward to the next few years with a great deal of interest and enthusiasm.

ALBERT G. HILL

Vice President, Administration and Personnel

In my report of a year ago, I commented on the growing influence of government on the affairs of universities. As I reflect on the issues and events of the year just past, I am acutely aware of the dominance of Federal programs and legislation among the matters which captured much of the time and attention of the senior staff in my area of responsibility. While these issues are reported on more fully in the reports of the department heads, it is worth noting some of them here.

The Employee Retirement Income Security Act of 1974 (ERISA) has required extensive attention over the past year to the provisions of our pension and other benefits plans. It has required the publication of information, presented in great detail, about all our benefits plans, and sharply limited us in certain ways (continuation of pension accumulation for faculty members on leave, for example), all at considerable cost in senior management time and legal and actuarial services.

Policies and procedures for coping with potential conflicts of interest were high on our agenda during the past year, leading to the adoption of a new Institute policy statement and requests to the faculty and staff to report on their outside activities and interests and to disclose any with potential for conflict with the Institute interests. While, in terms of conflicts arising out of outside professional activities, the Institute had been alert to the potential for many years, recent court decisions and legislation as well as Federal inquiries at some other institutions into the extent of outside professional activities stimulated the comprehensive review of our own policies.

Proposed Federal changes in the regulations governing affirmative action on behalf of women and members of minority groups required extensive analysis of the implications of the changes and the formulation and communication of an Institute position in opposition to those changes which seemed to weaken affirmative action efforts.

In the same area, we have followed closely the Bakke case in which the US Supreme Court is being asked to judge whether a white applicant for admission to a University of California medical school was unconstitutionally discriminated against, having been denied admission, while minority applicants, assertedly less well qualified, were being admitted under a special program. The Court is here being asked to intervene in a university admissions process, a process we believe best left to university judgment. In this instance, the Institute joined with a number of other private universities in an amici brief urging the Court to uphold the right of the University of California to consider race as a factor in admissions as part of an effort to overcome past patterns of discrimination.

This year, also, the Institute was required to prepare a plan for the employment of the handicapped and to begin the process of reviewing its facilities and programs to assure that they are accessible to handicapped employees and students. Both of these actions are the culmination of an extensive process of analyzing and commenting on regulations prepared to implement Sections 503 and 504 of the Rehabilitation Act of 1973. The costs of making the accommodations required by the regulations cannot be clearly foreseen but are potentially very high.

We are now on the threshold of another piece of legislation of potentially major, but now unknown, impact on the universities, and which runs counter to one of our major initiatives of the past year. The proposed legislation, which seems likely to pass, bans mandatory retirement before age 70. The initiative of the past year is the culmination of our effort to develop an early retirement option to increase the attractiveness of retirement before age 65 and thus to increase the opportunity for new faculty and staff appointments. The full consequences of the proposed legislation cannot now be known, but it is almost certain it will diminish the opportunities for new appointments and force substantially increased time and attention to discovery of alternative means to renewal and vitality.

We can anticipate, as well, legislation on privacy of records of faculty, staff, and employees, comparable to the Buckley Amendment for students, now that the Privacy Protection Study Commission has issued its report. To the extent that the legislation requires that an individual have access to his or her personnel records, as seems likely, judgments of faculty quality in the appointment, promotion and tenure process will become immensely more difficult because those from whom evaluations are requested may no longer be assured of confidentiality. We already know, from the impact of the Buckley Amendment on admissions evaluation reports, that such reports become significantly less useful as a basis for making discriminating judgments.

A Federal program which we value highly, the College Work-Study Program, has this year demanded a great deal of senior-level attention: first as we sought, against adverse judgment of government convened panels, to document the needs and eligibility of our students for higher levels of financial support; and later as we attempted to use work-study funds in support of graduate student staff with a resulting collision between the Federally mandated detailed time accounting systems and the relatively unstructured nature of academic professional work. In the long run we can be hopeful of gaining recognition for the support of professional work on the part of our students and accounting and payment mechanisms appropriate to such work, but patient persistence of senior staff will be required to gain that end.

A final note on this theme, which adds emphasis to the growing influence of government in university affairs, is the special study requested by the Chancellor as to the best means of providing adequate legal services to the Institute at reasonable costs. Ten years ago it was a rare major private university which had inside counsel. Today many more do than do not, a response of many institutions to the fact that nearly all our decisions and actions have legal implications.

The pages which follow report in some detail on the activities of administrative departments in my area of responsibility. Some of the highlights are singled out here, however, for special emphasis.

Our target for the size of the undergraduate class entering in fall, 1977 was 1,000 students. Approximately 1,090 will register. This difference is attributable to a rather dramatic increase in the number of applicants accepting our offer of admission, from about 46 percent in 1976 to 56 percent in the current year. While the unexpected additional 90 students put severe pressure on our undergraduate housing system, the increased proportion of applicants responding favorably to our offer of admission is quite heartening.

The need for financial assistance for our undergraduates continues to rise; aggregate "need" (the total student budget less parental contributions) climbed above \$10,000,000 this year, and \$930,000 from M. I. T. 's unrestricted funds was used to help bridge the gap between our income from scholarship endowment and our requirement for scholarship funds. The Student Financial Aid Office, as mentioned earlier, directed a great deal of its time to developing and pressing the Institute's application for Federal financial aid funds, resulting in a 31 percent increase in initial allocations for the three campus based programs for fiscal year 1978.

The employment market for our students brightened this year. More private firms used the interviewing facilities of the Career Planning and Placement Office than in any year since 1968-69. Improved economic conditions are also reflected in the continuing decline in the number of alumni registering with the Alumni Placement Office.

During the year, the Institute concluded negotiations with four unions representing hourly paid employees in seven separate bargaining units. Total Institute nonacademic employment remains stable at around 6,000 persons, while an 11 percent increase occurred in the number of employees actively seeking lateral or promotional transfers over the previous year. An important event of the year was the completion of development of the central Personnel Information System. Another undertaking of significance is a major project to revise completely and expand the Supervisor's Manual of Personnel Policy into a comprehensive guide to personnel policies and procedures for employees and supervisors.

This year also saw the design and implementation of the Management and Supervisory Training Program at Lincoln Laboratory by the Office of Personnel Development. The program began as a pilot project last August and has now been presented in eight sessions to 200 participants. The program is intended to reach approximately 1,000 managers and supervisors over a three-year period, and emphasizes those responsibilities, issues, and skills associated with implementation of equal employment opportunity and affirmative action programs.

The Lincoln Laboratory program is an important arm of our Affirmative Action Plan, and throughout the Institute, department heads, supervisors, and others have worked hard to increase the representation of women and minorities in Institute employment. We continue, however, to be concerned about the lack of real progress in increasing representation, particularly of black Americans, in almost all employment categories. While we have continued to make changes in policies that we believe will further our efforts, this is an important item for our agenda as the new academic year begins.

M. I. T.'s child care services, also importantly related to our Affirmative Action Plan, have continued to be successful and useful, with the number of children using those services increasing by almost 25 percent over 1976.

An additional responsibility carried out again this year was the provision of staff assistance in the area of international programs, particularly assistance to the Ad Hoc Committee on International Institutional Commitments. The major focus was the preparation of the final report to the faculty, recommending the establishment of a permanent advisory committee.

INSITE, our computer system for inventory and accounting for space in M. I. T. buildings, has continued to be attractive to other institutions, with three new users joining the INSITE Consortium. The system also has proved its worth during the past year in providing the information in an auditable base as to the use of our facilities, to enable us to define more accurately our space costs for indirect cost recovery purposes.

The Working Group on Office/Clerical Issues, reported on in previous years, has continued to address concerns related to the biweekly employees' work environment. During the year, Working Group recommendations included revision of the Institute's Grievance Procedure, development of a new training program on M. I. T. administrative procedures, development of a "personal leave" policy for biweekly employees, development of a booklet providing guidance on performance evaluation discussions, and improvement of the biweekly vacation schedule. The Working Group continues to be active and effective with particular attention now being paid to the general work environment of biweekly employees and the classification system.

I would not wish to conclude this report without acknowledging our debt to all those in the administrative offices at M. I. T. who work with great commitment, often in unseen and unrecognized ways, to provide effective administration and support for our research and teaching processes. They merit our respect and our appreciation.

JOHN M. WYNNE

Office of Admissions

One year ago we were faced with a sudden drop in the percent of admitted students who chose to enroll at M. I. T. The only apparent fact that would explain this was the April 16 acceptance mailing date, later by three weeks than the year before. We had agreed to mail on this date in an attempt to gain more uniformity with the procedures used by the Ivy League. This year with an earlier date, March 24, we find our yield up to over 55 percent, which is both higher than at any time in the past five years and higher than the acceptance rate in all but a few colleges, and the class 85 students larger than was intended. An extra effort to show a personal interest in our applicants on the part of the staff, faculty, and members of the Educational Council played a part in this recovery. In many ways this year's class looks like its predecessors and is a group that compares favorably both academically and personally with any group of similar size in the world. The diversity of background and interests is unmatched. They are young men and women of truly magnificent potential.

The task of bringing this group together each year becomes more complex as time goes on. This year's positive results do not remove our concern for the long-term decrease in the number of college-age youth and the continuing increase in cost of an M. I. T. education. Rapidly increasing Federal government regulation of the admissions process is a fact of life. Many of the regulations that are proposed are consistent with our practices, but to meet the letter of the law requires considerable extra staff effort. The recruitment of the most talented students continues to be a challenging and stimulating task.

The Admissions Office interns this year, W. Thad Byrd, Mark W. Crane, and Kevin S. Campbell, all three studying at the Sloan School, supported the staff and faculty in their task. We will miss William J. Hecht who left the Institute for private employment, and Gail Wilson who leaves for the University of Pennsylvania law school.

PETER H. RICHARDSON

Office of the Advisor to Foreign Students

During the period covered by this report there were 1,488 citizens of other countries enrolled at the Institute from 88 nations. Given the total enrollment of 8,597 students in October 1976, this group represented 17.3 percent of the total student body. This is a slight increase over the previous year. The countries with delegations of 50 or more are: Canada, 115; Iran, 108; Hong Kong, 106; Republic of China, 103; India, 77; Japan, 77; United Kingdom, 59; France, 51.

In 1970-71 the representative countries with significant numbers of foreign students were Canada, 173; Republic of China, 110; India, 104; Hong Kong, 91; United Kingdom, 83; France, 50. Iran was represented by 26 students.

Aris J. Papadopoulos, Class of 1979, Chairperson of the International Students Association, and Victor J. Chang, Class of 1978, Chairperson of the M.I.T. Chinese Students Club, were recipients of the William L. Stewart, Jr. awards in May 1977, for their leadership roles in their respective organizations. The International Students Association has been responsible during the past year for bringing to the community a rich variety of cultural programs often coordinated with representatives from Wellesley College and other campuses in the Boston area. This group is also closely related to the intercultural programs of the World Affairs Council in Boston. Funds for this inter-university cooperative program were awarded for the third consecutive year by the US Department of State through the National Association for Foreign Student Affairs. The Advisor is a member of the Advisory Panel serving this program.

The M.I.T. Host Family Program placed approximately 200 new foreign students with alumni and friends of the Institute through fall, 1976. This program, organized in 1961, has introduced more than 2,000 foreign students to some 450 participating families in greater Boston. Mrs. Howard Johnson is the present chairperson. In addition, Mrs. Donald Harleman and Mrs. Robert Logcher sponsored a visit to Drumlin Farm this spring for the children of foreign families sojourning at M.I.T.

The significant International Open House program welcoming all new foreign students and staff to the Institute in the fall continued in its fourth year. It is an informal effort designed to help those new to M.I.T. to meet a wide segment of people from the Institute community. It helps focus in on the wide variety of services and programs that often may remain obscure to those new to this culture. This is a cooperative undertaking of Dr. Charlotte Schwartz of the Medical Department, hosts of volunteers, and the staff of the Foreign Student Office.

The traditional services of this office relating to the admissions of foreign students, counseling on matters of immigration, finances, housing, and employment have been carried effectively by Suzanne Carr, Laura Cummings, and Amy Church.

EUGENE R. CHAMBERLAIN

Office of the Educational Council

For 25 years the Educational Council has helped M.I.T. seek out the highest calibre young men and women as potential undergraduates. Though the Council has grown in size and activity, its basic mission remains unchanged -- maintaining the high standards of M.I.T.'s entering classes. In the face of more aggressive competition for the finest students from schools in every part of the country, the Council's immediate objectives are to work even harder to reach prospective students with information about the opportunities and excellence available at the Institute.

In many cases, the Educational Council is the only personal contact a student has with M.I.T., and the Cambridge office works to make that contact exciting, enlightening, and helpful. Office publications and communications with alumni by letter and phone are extensive; however, personal communication when Educational Counselors are on campus or by staff travel is still the cornerstone of our efforts.

The actual backbone of the Council is the more than 1,100 alumni volunteers without whom M. I. T. could not hope to compete effectively in the student marketplace. It is the hard work of these volunteers that produces the high number of quality applications and most recently the successful "yield." Much of the credit for the strength of this organization, however, must go to Mary Manning. She retired in May after 24 years with the Council. Her dedication, limitless energy, enthusiasm, and high professional standards will be sorely missed by everyone associated with the Council.

JOSEPH A. EDWARDS

Career Planning and Placement Office

The relevance of M. I. T. 's style of teaching and research to the needs of the world is nowhere more apparent than in the eagerness with which private firms and government agencies seek the Institute's graduates. To be sure, graduates in some fields in recent years have found the employment market depressed, and this was so again last year, but in general the demand for M. I. T. talent in 1976-77 showed characteristic strength. More private firms used the interview facilities of the Career Planning and Placement Office than in any year since 1968-69, the last of the boom years of the sixties. Recruiting by government agencies was down slightly from recent years but recruiting activity overall matched the level of 1969-70. In some fields, notably in chemical, electrical, and mechanical engineering, and at the master's degree level in management, there were more recruiters on campus than available students. Students seized the opportunity presented to them and the Career Planning and Placement Office, not to speak of other interview locations around the Institute, was the scene of over 5,600 interviews. This figure, too, approaches the traffic of the sixties.

Students also came to the Office in large numbers to discuss such questions as their choice of major, the opportunities in specific fields, techniques of finding a job, and the merits of individual employers. The enquirers ranged from freshmen planning their academic career at the Institute to postdoctorals worried about the funding of their stipends and the future funding of their disciplines. They made some 675 counseling appointments, while a considerable number of others simply walked in. To the students the questions they ask are frequently of momentous importance -- touching perhaps on the shape of their lives -- and the conversations tend to run an hour or more. The Office views this advice giving as a major responsibility. The flow of students through the doors suggests that they are finding it a useful place to turn.

Improved economic conditions were reflected in a continuing decline in the number of alumni registering with the Office. The number dropped to 454 from 522 in 1975-76 and 627 the year before. Characteristically, there was an increase in the number of job descriptions received from employers seeking experienced personnel. As usual, the strongest demand from employers was for recent graduates in fields enjoying current growth. A large part of the work of the Office is in helping alumni with more years behind them who wonder whether their careers have taken them in the right direction and who would like to explore the alternatives that may be open to them.

Note should be made of the work of Colonel Philip Schwartz, Class of 1923, who has provided invaluable help to alumni on the West Coast through his chairmanship of a placement committee in the M. I. T. Club of Southern California. He has generated a store of information bearing on opportunities in the California economy and given personal counseling to many

Student Financial Aid Office

alumni whose contact with the office in Cambridge could only be by mail. Alumni who have turned to him for help have shown their appreciation; to their thanks should be added the thanks of the M. I. T. community at large.

ROBERT K. WEATHERALL

Student Financial Aid Office

Each summer, the S.F.A.O. searches for more expressive ways to present its recurrent theme -- the need for financial assistance to undergraduate students grows again. Aggregate need (and total awards to meet the need) pushed beyond the \$10 million mark, while the scholarship supplement provided from unrestricted operating funds exceeded the level of the total scholarship program in 1958. Satisfying this need was a healthy, but all too unspectacular, increase in income from endowed scholarship funds together with a significant increase in the use of the Technology Loan Fund, increases of varying proportion in the several categories of outside-agency funds, and another large allocation -- \$930,000 -- from M. I. T.'s unrestricted income to fill the gap. Another substantial increase was recorded in the Federal Basic Grant program, as all four undergraduate classes became eligible for the first time. Our students received just over \$400,000 from this source, an amount that is likely to remain steady in the near future.

The influx of funds from the three major federal grant programs has reached heroic proportions. In addition to the Basic Educational Opportunity Grants, a total of \$365,786 was awarded from the Supplementary Grants program, and the equivalent of \$913,700 in awards was paid to R. O. T. C. cadets in the form of tuition grants, stipends, and allowances under that re nascent program.

Another unusually large total was given by alumni to support the scholarship program, in direct response to continued emphasis by the Alumni Fund. Otherwise, the growth of the traditional designated resources -- the endowment for scholarships and outright gifts from individuals, corporations, and foundations -- was typically modest.

This year the office decided to commit a substantial block of time to pressing the Institute's application for Federal aid funds through the entire appeals process -- through regional and national appeal boards and thence to the Office of the Commissioner of Education. The effort was eminently successful, resulting as it did in the realization of a 34 percent increase in Federal allocations for fiscal year 1978. In the light of rumor that changes in the application process for fiscal year 1979 will tend to lock schools into prior allocation levels, it was gratifying for M. I. T. to have attained this significantly higher allocation base.

In last year's report we mentioned our consideration of new means of accommodating the perceived need of parents of students not eligible for assistance through the S. F. A. O.'s need-based aid program. Through the combined efforts of the Director of Finance and the Knight Insurance Agency a Parent Loan Plan (P. L. P.) has been inaugurated at M. I. T. to relieve the immediate cash-flow burden of the Institute's costs. The P. L. P. is described more fully in the report of the Vice President for Financial Operations.

In response to increased demand for loans and work-study assistance by graduate students, the S. F. A. O. set about to improve the systematic assessment of graduate student need and the delivery of awards. Corollary to this activity, a project is under way to make available

to the Graduate School Office the data-processing system in use by the S. F. A. O., as a means of providing additional record-keeping and monitoring functions.

The Student Employment Office maintained an aggressive role in identifying jobs for students. Considerable growth was seen in the area of term-time employment, including the graduate college work-study employees, which totaled almost \$4,000,000 for some 3,451 students. For the 1977-78 academic year, the minimum wage of \$2.80 has been established for the student labor market, effective September 1977.

Early in the academic year Lawrence Maguire resigned as Director of the Student Employment Office to accept new responsibilities at Harvard College, and Nelson Armstrong replaced him.

Rita Nethersole, Class of 1975, joined the S. F. A. O. staff in May. Following the resignation of Gail MacDonald, who served the S. F. A. O. for 12 years, Elenore Kehoe assumed the post of Administrative Assistant in June.

JACK H. FRAILEY

Office of Personnel Development (O.P.D.)

The Office of Personnel Development experienced a busy year under somewhat stabilized funding conditions. Continued activity in ongoing functions such as tuition assistance, the Administrative Development Program, orientation for new employees, coordination of the Working Group on Office/Clerical Issues, technical typing classes, and updating and distribution of the "M. I. T. Guide to Administrative Offices" was supplemented by significant activity in several new areas.

In general, a great deal of effort has gone into designing and implementing management and supervisory development training programs at Lincoln Laboratory and on campus. The program at Lincoln Laboratory, which began with a pilot program last August, has now been presented in eight sessions to 200 participants. The mandatory 20-hour program, which is intended to reach approximately 1,000 managers and supervisors over a three-year period, emphasizes those responsibilities, issues, and skills associated with implementation of Equal Employment Opportunity and Affirmative Action programs.

Lincoln Laboratory and the Office of Personnel Development have been commended by the Department of Defense, as well as the Civil Rights Division of the Department of Health, Education, and Welfare for this program which is one of the only known efforts of this scope in an academic institution. The co-directors of the O. P. D. were invited to describe the program in a presentation at the National Conference of the American Association for Affirmative Action in May.

The overwhelming weight of participant evaluation response has been positive. More than 90 percent of the participants have rated the efforts of the O. P. D. staff as good or excellent; among all participants, 87 percent have reported some or considerable increased confidence in their ability to supervise according to the principles of Equal Employment Opportunity and Affirmative Action.

Based in part on the experience at Lincoln Laboratory, the O. P. D. has designed several variations on supervisory training for presentation to various groups on campus. These programs have been widely discussed and implementation will begin soon.

A series of six short seminars on performance evaluation were presented to more than 125 library employees prior to the April biweekly review. These seminars were attended by supervisors as well as biweekly employees, with benefits reported by both groups. The seminars were designed and presented by the O. P. D. at the request of the Libraries.

A new training program for biweekly and exempt employees, the Administrative Procedures Program, was presented to almost 200 M. I. T. employees recommended for participation by their departments. Departments have nominated an additional 250 employees for participation in future sessions of this program. Instructors are representatives of the following administrative departments: the Office of Sponsored Programs, the Purchasing Office, the Comptroller's Accounting Office (Accounting and Payroll divisions), Physical Plant, and the Personnel offices. Not only has their teaching been well received, but the instructors have indicated the value of this opportunity to disseminate information about their departments which contributes to more smoothly functioning operations for them.

The O. P. D. has continued to respond to periodic requests from departments for consultation in problem-solving situations and to assist in designing conflict resolution strategies, where conflict situations have been identified.

The co-directors of O. P. D., along with the Vice President for Administration and Personnel, participated in several exploratory meetings with the Higher Education Management Institute (HEMI). M. I. T. was among many institutions of higher education in the country invited to participate in the Exxon Education Foundation funded project, designed to produce programs of management development for universities. After several meetings, it was concluded that the approach, utilizing extensive survey feedback and the Likert model of organizational effectiveness for needs assessment, would not meet the current needs of M. I. T.

Highlights of activity in ongoing functions are summarized below. Applications for the Administrative Development Program were up; there were approximately 75 participants during the past year. The curriculum and instructional team for the financial management section of the program has been modified with apparent positive results. More than 300 employees attended orientation sessions, which have been modified to better meet the needs of new employees at M. I. T. New employees now receive the booklet, "You and M. I. T." which was finalized for distribution during the past year. Detailed statistics are not yet available, but it is estimated that approximately 700 employees will have used the Tuition Assistance Plan during the past year. There continues to be a modest (35 applicants) but regular demand for training in technical typing, which is not available in the Boston area outside of M. I. T. The Office of Personnel Development again sponsored two I. A. P. activities, scheduled at times convenient to M. I. T. employees. In total, almost 2,000 members of the M. I. T. community utilized the direct services of the Office of Personnel Development during the past year.

MAUREEN M. YAGODKA
F. ADAM YAGODKA

Office of Personnel Relations

Benefits Administration

The impact of the Employee Retirement Income Security Act (ERISA) of 1974 was a mandate for some major changes in the Institute's pensions plans and required a substantial volume of reporting to the Department of Labor, effective January 1, 1976. The Act also required an acceleration of an already planned series of booklet distributions to all employed personnel concerning each of our major benefits.

The scholarship benefit for children of faculty and staff was modified to provide a current dollar limit to the amount of benefit payment.

The Institute Health Insurance plans were amended to provide additional coverage for treatment of mental and nervous disorders. This was mandated by Chapter 1221 of the General Laws of the Commonwealth of Massachusetts, effective September 1, 1976.

Also mandated by Chapter 371 of the General Laws was an amendment to our plans to provide certain extensions of coverage for families of deceased employees and for employees on lay-off.

Labor Relations

Negotiations with four unions representing 1,700 hourly-paid employees in seven separate bargaining units were concluded in the latter half of 1976. The new two-year agreements provided for wage increases of 7 percent on July 1 of 1976 and 1977 and improvements in the vacation, pension, and life insurance plans. Negotiations with the Campus Police Association, a new unit certified by the National Labor Relations Board in February 1976, were still in progress as the fiscal year ended.

Activity under the grievance and arbitration provisions of the various agreements continued to increase and a new position of Assistant Manager of Labor Relations was authorized to assist in handling the workload. A total of 125 grievances were filed during fiscal year 1977 and 24 were pending arbitration as the year ended.

Wage and Salary Administration

The compensation structures of all categories of Institute employees were studied in relation to national and regional economic trends and competitive market conditions, and suitable adjustments were made to existing salary scales. In addition, the individual performance levels and job responsibilities of over 5,000 salaried employees were reviewed and appropriate merit increases determined and put into effect.

The Classification Task Group of the Working Group on Office/Clerical Issues continued its study of the biweekly classification structure. During the coming summer this group will

attempt to develop a series of comprehensive classification descriptions applicable to a number of functional areas including those in the library, data processing, and accounting areas. It is hoped that in the near future improved classification descriptions can be prepared that will encompass all biweekly job categories and that these descriptions and the information obtained in their development will enable the Task Group to further evolve a workable recommendation concerning possible improvements in the Biweekly Classification System.

ROBERT J. DAVIS

Office of Personnel Services

The Office of Personnel Services has continued its efforts to provide information and counsel on personnel matters to members of the Institute community. This year a one-day planning session was held on Saturday, February 5, to identify policy tasks and information needs for the year. The entire staff of the office attended the meeting, which was divided into three informational sessions in the morning and workshops on five topics in the afternoon. Some of the issues discussed were the budget outlook for fiscal year 1978, internal procedures, training needs, and public relations. It was an extremely productive day during which almost 30 policy and procedural work groups were created or their progress to date reviewed. Priorities were established for task completion this year and next.

Employment Analysis

Total Institute nonacademic employment as of March 31, 1977 was 5,969: 4,106 on campus and 1,863 at Lincoln Laboratory, a net increase of 53 employees on campus and a decline of 45 employees at Lincoln Laboratory.

In spite of efforts to increase the representation of minority group members, the data shows a .3 percent decline in minority employment (9.8 percent to 9.5 percent). More encouraging, however, is a small increase in the representation of women in nonacademic, professional positions; the proportion of women on the Administrative Staff has increased from 31 to 35 percent, while on the Sponsored Research Staff it has remained stable at 13 percent.

Total nonacademic employment activity declined slightly this year in comparison to the previous year. The number of available positions during the period from April 1, 1976 to March 31, 1977 dropped from 1,217 in the same period a year ago to 1,185 positions (-2.6 percent). However, there was a 7.6 percent increase in the total number of applicants from 3,352 to 3,606. This level of applicant flow almost exactly corresponds to that of two years ago (3,608). Of the 3,606 persons who applied for M.I.T. positions, 2,799 were interviewed in our office (an increase of 171 persons over last year) and 2,453 were referred to supervisors having positions available.

In addition to these outside applicants, 574 Institute employees applied for transfers during the period from April 1, 1976 to March 31, 1977. This activity represents a substantial increase (11.2 percent) in the number of employees seeking lateral or promotional transfers over the previous one-year period. Of the 572 transfer candidates referred to one or more job openings, 206 were successfully placed. This year's placement rate of 36 percent was 12 percent higher than that of the previous period.

The sources of referral of applicants for employment continued to follow historic trends. Referral from Tech Talk advertisements, former employees, current employees, and students accounted for more than half of those who applied this year. Advertising and agency (nonprofit and profit) referrals comprised 12.8 percent of the total and "interest in working at a university" attracted another 12.8 percent.

Committee Work and Other Activities

While applicant and transfer interviewing and referral required the largest portion of staff effort again this year, personnel officers continued to devote significant amounts of time to other functions, including career and personal counseling, labor relations, grievance mediation, and salary reviews. In addition, members of the staff have been involved in special program assignment, Institute committee participation, union contract negotiations, and internal policy development. For example, Evelyn Perez took charge of the summer program which employed 13 Cambridge youths with funding support from the Cambridge Economic Opportunity Committee, Dick Cerrato took responsibility for the ex-offender program, and Susan Lester and Peggy O'Brien were members of the Institute's Task Force for the Employment of the Handicapped.

Six members of the Personnel Services staff have done extensive committee work on the benefits, classification, work environment, performance evaluation, and grievance procedure task groups of the Working Group on Office/Clerical Issues. The work of these task groups has resulted in a number of new policies and procedures, including a clarification of the non-union grievance procedure, a personal leave policy, and a pamphlet designed to assist supervisors in conducting performance evaluations.

New Programs

An important event at the beginning of this year was the completion of the development of the central Personnel Information System. Following installation on July 1, 1976, significant programming refinements and data improvements were undertaken, which have contributed greatly to the operational and analytical functions of the office. Work was begun on the installation of supplementary benefit and historical record modules and systems work was accomplished to support an expansion of the telephone directory to an all-employee directory this coming fall.

A successful orientation program designed to familiarize secretarial school placement directors with employment opportunities at M. I. T. was also initiated this year under the direction of Peggy O'Brien, Employment Coordinator. The half-day program began with a discussion of job content, qualifications, and compensation by M. I. T. secretaries and members of the personnel staff, and was followed by a tour of campus and a luncheon discussion.

Finally, a major project was undertaken to completely revise and expand the Supervisor's Manual of Personnel Policy into a comprehensive guide to personnel policies and procedures for use by supervisors and employees. Susan Lester, Employment Officer, has assumed full responsibility for this important task and has formed an advisory group of members of the Institute community having responsibility for personnel questions in their departments, who will provide general review and critique of the Manual as it evolves. She also chairs the newly formed Personnel editorial group.

CLAUDIA B. LIEBESNY

Affirmative Action Program

This has been a complex and eventful year for those of us who are responsible for the development and implementation of affirmative action/equal opportunity programs at the Institute. National attention was focused during the year on two major issues involving affirmative action and the universities. M. I. T. was not indifferent to these issues. In fact, the Institute formally established positions on both issues which are viewed by some to be among the most critical since the affirmative action effort was initiated.

Last winter a new set of guidelines for implementing Executive Order 11246 was proposed by the Department of Labor. These changes were viewed by many civil rights activists as demonstrating evidence of retrenchment and being likely to lessen efforts and weaken enforcement mechanisms. Several members of the Institute community studied the revisions and on behalf of the Institute strongly recommended to the Department of Labor no major changes pending an extensive, research based nationwide evaluation of the affirmative action program. In summary, the comments emphasized that, "One of our difficulties in assessing the merits of the proposed changes in the regulations is the absence of objective data on the effectiveness of the existing regulations and their administration. Like many other institutions, we share a desire to see affirmative action regulations more lucid, internally consistent, less time-consuming, and more effective. We would like to see greater consistency of enforcement around the country, and believe that most compliance agencies could respond more swiftly and efficiently.

"It is not at all clear to us that the proposed changes in the regulations adequately address these concerns. In a number of ways they seem to signal a lessening of emphasis on affirmative action compliance without any evidence supplied that, on balance, the changes are likely, in fact, to increase employment and promotional opportunities for women and members of minority groups. We urge that, for now, the changes be limited to those which clarify requirements and expectations and simplify administration without lessening effectiveness. We urge, as an alternative to the proposed full-scale revision, a carefully-designed, nationwide evaluation of the Federally-mandated affirmative action program to determine its strengths and weaknesses and to provide a sound research basis for the redesign of the program and implementing regulations."

The other issue, and perhaps the more crucial one, is *Allen Bakke v. Board of Regents*, a case involving admissions procedures at the Medical School of the University of California at Davis. The case, alleging "reverse discrimination" in the university procedures, will go before the US Supreme Court in the fall. If the decision is against the University there is a serious risk that admission of minority students will be curtailed and the gains of the past decade reversed and all programs calling for affirmative action may be adversely affected.

M. I. T. joined with a number of other private colleges and universities in support of a brief filed with the US Supreme Court urging that consideration of racial minority status as an element in admissions decisions be held constitutional. The brief urges the reversal of the judgment of the California Supreme Court, which ruled that the special admission program at Davis is unconstitutional in that it constitutes racial discrimination against non-minority applicants. M. I. T.'s decision to support the brief was made because of the conviction that a judgment against the University of California would jeopardize efforts the Institute has made over the past decade to increase the numbers of minority graduate and undergraduate student enrollments.

On campus, activities varied from instituting new programs to implementing established goals and objectives. One major accomplishment this year was the development of a written program on the employment of handicapped individuals. The essential elements of the program include: 1) a policy that the Institute will not discriminate against any qualified employee or applicant because of a physical or mental handicap, in its recruitment, promotion, compensation, or other employment practices; 2) a policy that the Institute will make "reasonable accommodation" to the known physical or mental limitations of an otherwise qualified handicapped applicant or employee; 3) a commitment to undertake outreach and recruitment activities intended to encourage handicapped individuals to apply for positions at the Institute for which they may qualify; and 4) to plan for the elimination of architectural barriers which limit the accessibility to handicapped persons of Institute programs and activities.

This Program covers both Sections 503 and 504 of the Rehabilitation Act of 1973, including the new regulations on employment which were effective June 3, 1977. Those regulations also prohibit discrimination because of handicap against otherwise qualified applicants for admission and require accessibility by handicapped students to our educational programs and facilities. We are required to conduct over the next year a self-evaluation of our conformity with these new regulations. Our plan is to get this under way in early fall of 1977.

As of July 1, 1977 we will conclude another two-year cycle in the biennial goal-setting procedures. At this time, an assessment of progress will be made and new goals developed for another two-year period through July 1979.

The report this year on the attainment of numerical goals to increase employment representation of members of minority groups and women at the Institute is not good. Shortfalls in meeting goals for blacks and women appear in most employment categories. The representation of blacks is particularly troublesome in view of a decline in numbers reported a year ago. The following summary of employment changes in the representation of minority group members and women in the academic and nonacademic areas compares the July 1977 goals to actual employment as of June 30, 1977.*

In terms of academic employment, on the faculty, the July goal for blacks was 30 (3%) and actual representation as of June was 17 (2%); for women 87 (9%) with an actual of 66 (7%); total minority representation was 73 (7%) goal and the actual was 75 (8%). The other academic staff goal for blacks was 33 (4%) compared to 19 (1%) actual; women 239 (27%) goal and 308 (22%) actual; and total minorities 123 (14%) goal and 141 (10%) actual.

In the nonacademic area, blacks comprised 17 (4%) of the administrative staff with a goal of 25 (5%); women 159 (34%) and a goal of 153 (32%); and total minorities represented 28 (6%) with a goal of 39 (8%).

The research staff continues to be an area of concern as was noted in previous reports. Part of the problem of black representation is faced in the faculty area's small applicant pools. As of June, blacks represented 21 (2%) with a July projection of 38 (3%); women comprised 187 (14%) with a goal of 190 (14%); and total minority representation was 99 (7%) and the goal was 93 (7%).

There was a slight increase in minority and women representation in the exempt category in spite of shortfalls in meeting July projections. Blacks represent 26 (4%) of this group compared to a goal of 29 (5%); actual number of women is 208 (32%) and a goal of 193 (30%); and total minorities comprise 34 (5%) of actual employment with a goal of 41 (7%).

*Variances in percentages caused by significant change in the total population in this category were unforeseen at the time the goal was set. Goals were not projected to include research affiliates, postdoctoral fellows, unsalaried guests and visitors to the Institute.

Office of Child Care

Representation of blacks and other minorities has always been greatest in the Office/Clerical and Hourly categories. Blacks comprised 124 (7%) of this group as of June with a goal of 203 (12%); total minorities represented 168 (10%) compared to a goal of 284 (16%). It should be noted that loss of 11 people from this group brought the representation down from the previous year. In the hourly category, the number of blacks remained stable at 193 (11%) with a projected goal of 208 (13%); women declined with a June actual of 197 (11%) but will exceed the July goal of 174 (11%); and total minorities represented 242 (14%) with a goal of 273 (16%).

In summary, the above analysis indicates lack of progress in almost all employment categories. We recognize the seriousness of this problem and have begun to explore alternative solutions.

We will, as in the past, continue to review our policies, always reaching for modifications and revisions which will maximize positive results from our efforts. This year, for example, a change was made in the search procedure to allow members of the Academic Council to influence a department's search plan before it gets under way. We will encourage greater involvement from all members of the Institute community. At the department level, steps will be taken to inform department heads and appointing supervisors of the problem areas. Emphasis will be placed on the importance of their role in assisting the Institute in meeting its goals and objectives. It is through their efforts that progress will be made.

Within the next few months, our intention is to focus on this concern with great intensity. The Special Assistants to the President and Chancellor for Minority Affairs and Women and Work, representatives from the Personnel offices, and other internal resources directly or indirectly involved with these matters will participate in a search for ways to improve our recruitment and retention of women and minorities at the Institute, especially at the faculty and staff levels.

PATRICIA A. GARRISON

Office of Child Care

The number of children using M. I. T. related child care services this past year increased by almost 24 percent over the previous year. A total of 245 children used the three on-campus programs: 100 children used the M. I. T. Family Day Care Program (F. D. C.), 104 used the Technology Children's Center (T. C. C.) Nursery School, and 41 used the T. C. C. Day Care Center.

The Swimming Program for Parents and Children enrolled 30 children who were between the ages of two and six. The program emphasized ways that parents can help their children to feel comfortable in the water as well as techniques for teaching them swimming skills and water safety.

Family Day Care

M. I. T. Family Day Care is a program which provides full and part-time care to children from four weeks to seven years of age, in the home of the day care provider. In addition to the 100 children enrolled in F. D. C. , 33 children of the F. D. C. providers also benefited

from the program. Out of a total of 45 providers who registered with the Child Care Office, 38 actually had children placed in their homes. All M. I. T. Family Day Care providers are registered with the State Office for Children and meet the State's regulations governing Family Day Care. As in the past, most of the M. I. T. providers were the wives of foreign students.

Of those M. I. T. families who placed their children with the F. D. C. program, 44 percent had a student affiliation, 10 percent had faculty appointments, 19 percent had other academic appointments, 12 percent had staff affiliations, 16 percent were employees, and 2 percent were from the Charles Stark Draper Laboratory.

As is the past, most of the Children (87 percent) placed in Family Day Care were infants (up to 15 months old) and toddlers (15 months to 33 months). Nearly half of all children placed in F. D. C. this past year were under 12 months old as compared with 30 percent the previous year.

Technology Children's Center, Inc.

T. C. C. is a private corporation which operates a nursery school and a day care center on the M. I. T. campus. Both programs serve members of the M. I. T. community. Non-M. I. T. families are admitted when space is available.

Student families continue to be the primary users of the Nursery School, accounting for 68 percent of the enrollment. For many non-English speaking children the cooperative nursery school provides the perfect environment in which to become acclimated to their new living arrangements. The curriculum is born out of the diversity of language and customs. Children and their parents are encouraged to feel proud of their own language and culture while they become comfortable with new and often very bewildering ways of living.

Of the families using the Day Care Center, 27 percent had a student affiliation, 15 percent had faculty appointments, 12 percent had other academic appointments, 17 percent were staff, 34 percent had biweekly affiliations, and 2 percent were from Draper Laboratory. (Seven percent of the families have a dual affiliation.)

Of the 41 children using the Day Care Center this past year, six received financial aid made available by the Institute. All the families whose children received aid were on the biweekly payroll. Five were single parent families. The weekly subsidy averaged \$26 per child.

The basic difference between the Nursery School and the Day Care Center is the amount of time children spend in them. Because a child attends the Center all day, year round, the children in the program must necessarily rely upon the staff for important nurturing and custodial care (routines) that are necessary to the healthy development of all children. The Center staff views these routines, such as eating, dressing, brushing teeth, etc. as important learning experiences and opportunities, as indeed they are, and so are able to provide an enriched and enriching experience for the children in their care.

Both the Nursery School and the Day Care Center experienced rather severe underenrollment during the first term. Thankfully the situation reversed itself during the second term. Under these circumstances, the Board of Trustees felt it crucial to examine carefully what kinds of services the M. I. T. community needs and whether those needs are being met either here at M. I. T. or elsewhere. As a result, the Board is looking at the feasibility of operating a kindergarten program that would encompass all-day care.

It is worth noting that more and more working women are inquiring about child care as much as three to six months before their babies are due. The number of babies placed in F. D. C. at three months or less has increased by five percent and currently stands at 14 percent of the total. It would seem that a maternity leave policy which assures a woman of her job and the availability of good child care services is making it possible for those women who desire it, to return to work.

MARGARET SAND

Office of Facilities Management Systems (O.F.M.S.)

Fiscal year 1977 saw three new users of INSITE, M. I. T. 's computer system for inventorying and accounting for space in buildings. The new users include: New York University; Group Health Cooperative of Puget Sound; St. Luke's Episcopal Hospital, Texas Children's Hospital, and the Texas Heart Institute. This brings to 20 the number of institutions which employ the INSITE system and its associated methodology to manage their inventories of building space.

To train these new users and old users alike, the O. F. M. S. taught four one-week courses in the INSITE computer language and in the associated methodology for maintaining a space inventory. In addition, O. F. M. S. sponsored a one-day conference for all of the existing Consortium members to exchange information on facilities management techniques, and a one-day workshop preceding the conference to continue the training of those already using the system. Approximately 50 people attended each event.

To further assist the Consortium members in reaping the fullest benefits of the INSITE technology, a central responsibility for Consortium-member support was instituted. John B. Bidwell was assigned the responsibility to handle all Consortium member inquiries as well as to make an on-site visit to each Consortium member twice annually. These visits by Mr. Bidwell proved to be both extremely valuable in the maintenance of our professional obligations to each member as well as an excellent opportunity for him to bring back to M. I. T. useful ideas and state-of-the-art facilities management techniques.

Through the prime efforts of Mr. Bidwell and J. Terence Meehan of our staff, we accomplished a major task of converting the existing space inventory data base of one of these new users, New York University, into an INSITE data base. Under the editorship of Christine Hendrickson, with all the staff contributing articles, O. F. M. S. also published a re-formatted issue of INSIDE INSITE, a newsletter on facilities management with a circulation of approximately 350.

The Space Cost Analysis system (SCAN) continued to be field tested within the Consortium of INSITE users. Just prior to a maternity leave taken by Judith Lugas, formerly our Facilities Data Manager and now promoted to the position of Senior Applications Analyst, a two-day training course on SCAN for INSITE users was conducted. The participants included staff from the University of Alabama in Birmingham, the Rush-Presbyterian St. Luke's Medical Center in Chicago, and Syracuse University in New York.

Under the direction first of Ms. Lugas, and then her replacement, Laxmi Rao, there were two major updates to the M. I. T. space inventory data base, one in January and one in March. Each update was followed by the distribution of reports to the various administrative officers. Special reports from both the INSITE and SCAN systems were produced throughout the year for the Committee for Review of Space Planning (C. R. S. P.), Physical Plant Department, Director of Finance, Comptroller, Dean of the School of Engineering, and the Planning Office.

Also instituted for the first time was an annual audit of the 7.3 million gross square feet of space at M. I. T. by our Facilities Inventory Auditor, Thomas E. Donnelly. This effort was made in order to provide the required accurate, timely, and auditable space records for our reimbursement formulae to determine the portion of the annual \$17,000,000 plant cost pool that is associated with sponsored research. During the audit, other data was also gathered and reported to the Safety Office, Campus Patrol, Telecommunications Office, Purchasing Office, and the Physical Plant Department.

Under the auspices of the Summer Session, O. F. M. S. Director Kreon L. Cyros organized a one-week course on Facilities Management Systems and Inventory Techniques. There were 31 attendees from both the United States and foreign countries. Messrs. Bidwell, Meehan, and Cyros were among the speakers from O. F. M. S. John M. Wynne, Vice President for Administration and Personnel, to whom O. F. M. S. reports, also participated in the program.

Mr. Meehan participated in the M. I. T. Administrative Development Program. Martha P. Pennell and Mr. Bidwell continued to assist the M. I. T. Parking Committee in its use of a car-pool matching program. Mr. Cyros participated in the Northeastern Association of Institutional Researchers Workshop at Princeton University and chaired a panel on the Fiscal Implications of Facilities Management at a Montreal International Forum of the Association of Institutional Researchers.

KREON L. CYROS

Vice President, Financial Operations

The financial operating results for 1977 show the Institute to have come back essentially into balance between income and outgo on a current basis. The budget for 1978 and the present financial plans for 1979 and 1980 reflect the sustaining of that operating mode. All of this is a source of considerable satisfaction to the entire community and, particularly, to the senior officers who have carried the heavy part of the burden of reversing the trend of operating gaps and deficits of the early 1970s and of overcoming the almost insurmountable effects of the energy driven inflation of the more recent periods.

In no way, however, should the more favorable results for 1977 and projections for 1978, 1979, and 1980 be interpreted to mean that the Institute has solved its overall financial problems. The persistent year-to-year requirement for additional unrestricted funds, while reduced substantially in the last few years, remains to be fully resolved. The use of nearly all of the current unrestricted gifts, grants, and bequests for current operations, while very necessary the past few years, is a practice which has been followed very reluctantly. The return to a regular policy of adding such funds to endowment, using them for other capital needs, and for the creation of new programs, remains a near-term high priority goal.

Sponsored research activities continue in a healthy state with considerable growth taking place in the Energy Laboratory and the National Magnet Laboratory. In addition, the establishment of the Plasma Fusion Center, covered in more detail in other parts of this report, represents a significant forward step in that field.

The problems which arise in coping with external forces, particularly the Federal establishment, are ever present and are enough to test the best that is in us. Nevertheless, we in the financial operations' group consider 1977 to have been a very good year and we look to the future with confidence, cautious optimism, and enthusiasm.

The reports of the heads of the major departments reporting to this office follow. A very comprehensive and detailed accounting and reporting of the Institute's finances is available in the companion publication Report of the Treasurer 1977.

STUART H. COWEN

Audit Division

Internal auditing is an integral part of the management team of M.I.T. with specific responsibilities to assure management of the reliability of financial and operating data; that policies, procedures, and internal controls are adequate; and that the Institute's assets are safeguarded and utilized in a prudent manner.

The department is organized with an Institute Auditor and two managers directing the general financial audit area, and with EDP auditing. The total Audit Staff consists of seven professional auditors.

Electronic Data Processing Auditing (EDP)

The EDP Audit Staff has responsibility for the review and evaluation of data processing -- manual and computerized systems. The scope of the review includes five major areas: Application Systems in Operation, Systems Development, Post-Installation Audit, Operational Reviews, and Operating Systems and Management Services. The evaluation process is predicated on the review of system proposals, system analysis and design, programming, internal controls, system testing, and the implementation of the system. It includes such areas as operating system software, hardware, peripheral devices, operational auditing, and the management of the total data processing environment. The staff is a member of the Business System Development Advisory Group and is participating in systems planning. The thrust of the EDP Audit Staff has been in the area of student related systems with audits of the Registrar's System, Student Accounts Receivable System and Student Loan System, and management services in the Student Financial Aid Office.

In data processing, as new systems are developed, we expect increased participation in systems development and in the evaluation of recently installed systems. A continuing effort for review and integrity in the older data processing systems is maintained.

General Auditing

The General Audit Division conducts financial audits, departmental reviews, cost transfer reviews, and business procedure reviews. Financial reviews verify the activities of revenue producing units (such as the M.I. T. Press and the Faculty Club) as compared to departmental reviews which ascertain adherence to Institute policy and procedures by the laboratories, centers, and departments. Cost transfer reviews give special attention to the problems created by the transfer of material and service costs as well as the distribution of professional effort between research projects, while business procedure reviews consist primarily of verification and control over the Institute's assets.

During 1976-77, the emphasis was on departmental reviews and cost transfer reviews ranging from an overview of a department's operations to the recommendation of new operating procedures, implementation of internal controls, and establishment of budgeting techniques.

The Audit Division maintained liaison with the government and independent auditors who review the Institute's books for certification purposes.

Estates and trusts and court accountings relating to bequests to the Institute were reviewed as requested by the Treasurer's Office.

The audit schedule for the calendar year 1977 continues heavy emphasis on departmental reviews to improve the internal control and the management awareness of the needs for budget planning and account evaluation. We feel that this concentration of effort will provide the greatest benefit to the Institute in the support of the present accounting system and the assurance of the validity and currency of financial data.

EDWARD L. MC CORMACK

Comptroller's Office

During fiscal year 1977 effort continued toward the eventual implementation of a new integrated payroll system. With the purchase of a software package now completed, significant progress is anticipated during fiscal year 1978.

Student Loan notes receivable have reached \$24,750,000 as of the end of fiscal 1977, an increase of 12 percent over the prior year. These notes are funded by approximately \$8,300,000 of M.I.T. loan funds established by friends and alumni of the Institute; \$11,100,000 of Federal funds in support of the National Direct Student Loan Program (NDSL); \$550,000 in funds borrowed from the Federal government to support our contribution to the NDSL Program; and \$4,800,000 borrowed from a local bank.

In conjunction with the Administrative Computing Services (A.C.S.), the design of a new employee and general accounts receivable system has essentially been completed. This new system will also encompass the M.I.T. Faculty Club. Programming and testing are continuing and the system should be operational early in fiscal 1978.

Personnel Changes

There were several staff changes during the past year. The promotion of Joseph R. Cullinan to Senior Accounting Officer for Payrolls in April 1976 was omitted from last year's report. Harvey J. Connor, who has been with the Institute since 1966 in various capacities, was promoted to Staff Accountant in the Cashier's Office in October 1976. Steven A. Lanney, who joined the Institute in April 1975, was promoted to Senior Staff Accountant in February 1977. Also in February, Stanley Miller was promoted to Senior Accounting Officer for Benefits. During that same month, John P. Leonard was named Associate Comptroller. James F. McTighe, with the Institute since 1971, was promoted to Senior Staff Accountant in April 1977. Robert R. Ragusa was promoted to Comptroller's Personnel Administrator in May 1977. Mr. Ragusa replaces Thaddeus W. Kowilcik who retired on June 30 after 32 years of service to the Institute. William M. Toscano, who joined M.I.T. in July 1975, was promoted to Staff Accountant in June 1977.

PHILIP J. KEOHAN

Lincoln Laboratory Fiscal Office

Funding

New funding provided during 1976-77 totaled \$118.7 million. These funds were authorized to cover Lincoln Laboratory operations through September 30, 1977, the end of the new government fiscal year. The Department of Defense continues to provide the principal support for the Laboratory, furnishing 91.6 percent of the total. Other funds were provided by the Federal Aviation Administration (4.2 percent) and the Energy Research and Development Administration (2.9 percent). The balance of the support was provided by the National Science Foundation, Bureau of Mines, and the Nuclear Regulatory Commission.

Research Volume

The volume of sponsored research performed at the Laboratory during the year totaled \$88.1 million as compared to a total of \$92.5 million last year. The decrease was accounted for in subcontract and other outside procurement activities. These activities are expected to return to normal during the 1977-78 year. The 1976-77 total volume includes \$511,000 representing the cost of research performed by on-campus laboratories for Lincoln Laboratory. In addition, 25 M.I.T. faculty members and 20 graduate students participated in research programs at the Laboratory during the year.

Personnel Changes

Thomas Saxon elected to take advantage of the M.I.T. early retirement option effective June 30, 1977, after 23 years of service with the Lincoln Fiscal Office. Elizabeth C. Nelligan, who has been with the Institute since 1955, was promoted to Section Supervisor and will be responsible for banking relations and all other cash receipts and disbursement functions formerly under the direction of Mr. Saxon.

ROBERT V. DODD

Office of Sponsored Programs (O.S.P.)

For fiscal year 1977, the total volume of sponsored research performed on campus is expected to approximate \$106,200,000, an increase of 12.6 percent over the fiscal 1976 volume of \$94,343,000.

As shown in the tabulation below, the fiscal 1977 on-campus research supported by three Federal agencies is likely to exceed \$20 million each after significant growth over the past 10 years.

Campus Research Volume by Sponsor

(In thousands of dollars)

	<u>1967</u>	<u>1972</u>	<u>1976</u>	<u>1977 estimate</u>
Department of Defense	17,477	14,731	13,220	12,600
Energy Research and Development Administration	8,089	7,607	13,923	20,750
Department of Health, Education and Welfare	6,411	11,460	17,334	20,250
National Aeronautics and Space Administration	6,267	11,422	7,004	7,700
National Science Foundation	5,508	11,274	20,845	22,100
Other Federal Sponsors	<u>1,548</u>	<u>3,329</u>	<u>5,007</u>	<u>6,000</u>
<u>Total Federal Sponsorship</u>	<u>45,300</u>	<u>59,823</u>	<u>77,333</u>	<u>89,400</u>
Industry	2,045	1,595	5,504	6,400
Foundations and other Nonprofits	2,606	7,735	8,832	8,200
Other	<u>646</u>	<u>1,505</u>	<u>2,674</u>	<u>2,200</u>
<u>Total Non-Federal</u>	<u>5,297</u>	<u>10,835</u>	<u>17,010</u>	<u>16,800</u>
<u>Total Research Volume</u>	<u>50,597</u>	<u>70,658</u>	<u>94,343</u>	<u>106,200</u>

Research Facilities

Establishment of a Plasma Fusion Center to serve as an intellectual and administrative focal point for work in plasma physics and in fusion was announced in September 1976. A major objective of the new Center will be to correlate work in the magnetic confinement area (Alcator) with other theoretical and experimental work at the Institute. In addition to work on confinement systems, there are strong complementary programs in plasma confinement theory, experimental plasma research, conceptual studies on future fusion power plants, and research in basic technologies of critical importance to fusion power presently under way at M.I.T.

On January 12, 1977, M.I.T. was officially designated a Sea Grant College at ceremonies attended by the Undersecretary of Commerce and the Administrator of the National Oceanic and Atmospheric Administration (NOAA). Eleven other universities are so designated, but M.I.T. is the first private university in the nation to win that status, the highest level attainable in the Sea Grant Program. M.I.T.'s link to the program began in 1968 when it became the first university to receive Sea Grant support for a research project.

In June 1977, it was announced that Harvard University and M.I.T. have formally established an inter-university Division of Health Sciences and Technology to focus science and technology on human health needs. Establishment of the Division is the latest step in a growing process of collaboration between the two universities which began in 1970 with the Harvard-M.I.T. Program in Health Sciences and Technology. The purpose of the collaboration is to apply the complementary strengths of both universities to the development of new kinds of physicians and other health professionals and to the application of modern science and technology to health and medical problems.

Graduate Student Support Programs

During fiscal 1977, approximately 315 graduate fellows and trainees received \$2.6 million in Federal support independent of specific research projects (but including National Institutes of Health training grants and National Research Service Awards). This compares with 360 students who received \$2.8 million in such support in fiscal 1976.

In addition, graduate research assistant salaries charged to sponsored research projects totaled approximately \$10,277,000 in fiscal 1977 compared with \$8,796,000 in fiscal 1976. Fiscal 1977 was the first year in which a reduction in the indirect costs applied to research assistant salaries and wages became effective. Lowering the cost of employing research assistants on research projects is intended to provide greater incentive for their employment.

Personnel Changes

During the year, the following staff changes occurred in the Office of Sponsored Programs: Patricia J. Greer was promoted to Assistant Director as of January 1, 1977; Donna M. T. Herlehy, formerly Assistant Director in the Office of Grants and Contracts at Children's Hospital Medical Center, joined O.S.P. as Assistant Director on January 1, 1977; Maureen K. Huguenin, formerly an administrative assistant in the Department of Earth and Planetary Sciences, transferred to O.S.P. as Assistant to the Director on March 15, 1977; James E. Grayson, formerly Administrative Officer for the Sea Grant Program, is transferring to O.S.P. effective July 1, 1977; and John W. Vitt, Jr., Assistant Director, retired after 31 years of dedicated service to the Institute.

GEORGE H. DUMMER

Office of the Director of Finance

The more favorable financial trends of the last two years continued through fiscal 1977. The need for additional unrestricted funds to balance operations dropped from \$6,493,000 in fiscal 1976 to \$5,801,000 in fiscal 1977, a decline of almost 11 percent. This need was met in part from current year revenues of \$1,308,000 from the Use of Facilities Allowances, \$629,000 from Patent Revenues, and \$3,738,000 from Unrestricted Gifts, Grants, and Bequests. These three sources of current year revenues fell \$126,000 short of the total need of \$5,801,000. This shortfall was made up by using other fund balances, primarily the investment income from the research reserve, which could be drawn upon to support specific activities.

The need to use other fund balances to support the Institute's activities has dropped dramatically since 1974. The budget adjustment program as well as a number of favorable circumstances, including the moderating inflation rate in the Boston area combined with additional students, and growths in research, private giving, and investment income, helped to bring current revenues nearly into balance with expenses.

The budget program for 1977 resulted in a gross budget adjustment of \$3,315,000 which yielded a net savings of \$2,100,000 in unrestricted funds and a net savings of \$1,215,000 in sponsored research funds used for indirect costs. As in prior years, these adjustments took two basic forms. First, there are expense reductions resulting from reduced services, consolidation of functions, or the application of new technological advances. Second, there are new methods of funding existing activities such as new revenue sources or the application of income from

endowment or similar funds. As the Institute's budget moves closer to dynamic balance, that is, expenses and revenues grow at the same rate, the need for a budget adjustment program of the magnitude of the last few years will diminish.

During fiscal 1977 a two-year budgeting program was started covering fiscal years 1978 and 1979. This two-year budget cycle helps to provide the individual departments with greater flexibility, both in planning their future activities and in meeting any budget adjustment targets established for their area.

In the fall of fiscal 1977 the decision was made to move ahead with efforts to redesign the budget system. A project team was established involving the Office of the Director of Finance, the Office of Business Systems Development, and the Center for Information Systems Research. In an effort to provide a more effective budget system for the Institute, the project team is currently studying our existing budget system, investigating systems at other colleges and universities, establishing requirements, and soliciting suggestions through discussions with M. I. T. departments. We are anticipating completion of this project in fiscal 1980.

A significant step was taken this year to extend the range of programs available to help students and their families meet the rising costs of an M. I. T. education. In response to a need that has been expressed by many middle-income families, M. I. T. developed a Parent Loan Plan (P. L. P.) to help parents pay for four years of undergraduate costs over an extended period of time, normally six and one-half years. The intent of the Plan is to provide some assistance to those families with income between \$15,000 and \$60,000 who are ineligible for M. I. T. 's Student Financial Aid Program, or, even if eligible, who need help in meeting the expected parental contribution. M. I. T. provides the basic funds for these loans with interest charged at an annual percentage rate of 8.75 percent.

Descriptive information on the new Plan was sent to the parents of the students offered admission to the Class of 1981. We expect the families of about 90 students, including some upperclassmen, to take advantage of the P. L. P. during the 1977-78 academic year. The program will continue to grow over the next several years as each new entering class is offered the P. L. P.

JOHN A. CURRIE

Vice President, Operations

Several important organizational changes took place this past year which are working well and deserve mention at the outset of this report. These changes were designed to consolidate and make more responsive several administrative functions.

The functions and personnel in the Planning Office involved in building programming and design, and those of the Purchasing Office involved in interior furnishings and design, were joined to the engineering and construction section of the Physical Plant Department to form a group which can now deal comprehensively with all aspects of our design, engineering, and construction activities. Harry Portnoy was promoted to Campus Architect with responsibility for this group. The Planning Office, under O. Robert Simha, was thereby freed up to concentrate on long-range physical planning issues that have demanded increased attention. Responsibility for the Planning Office was transferred to the Vice President, Operations as part of these moves.

Another operational and organizational change concerns the activities of the Graphic Arts Service. The costs of printing, copying, and related activities have become significant at the Institute. Some of this work is accomplished "in house" and some is purchased from outside vendors. Overseeing these activities centrally with the ability to realize significant economies by using the best source in each circumstance has been a desired goal in recent years. In addition, through the central purchase of a number of previously leased copying machines, other economies are being realized as well. That part of the Purchasing Office staff covering this type of activity was transferred to the Graphic Arts Service so that now we are able to make prompt, informed, and cost-effective decisions in this area.

Also of general operational concern, mention should be made of the quarters formerly occupied by the Charles Stark Draper Laboratories now vacant since their move to their new building. These facilities will provide opportunities for relocation and consolidation of other Institute groups and activities. Studies are now under way to determine how best to deal with them.

PHYSICAL PLANT

Utilities

The emphasis in our energy conservation activities during fiscal year 1977 shifted somewhat from a primary concern with modified and improved operating techniques toward conversion and changes in building systems and equipment. This effort parallels the integration of our Facilities Management System (F. M. S.) into the operation of the heating and ventilating equipment of our 34 highest energy consuming buildings, and represents permanent modifications in those building systems which are being put under central control for greatly improved efficiency in the use of energy.

The Facilities Management System is, for all practical purposes, now installed. The devices which are to be monitored or controlled have been wired into the system. Generic software

packages are complete and specific applications subroutines (individual building heating, ventilating, and air conditioning systems/subsystems) are being debugged and optimized one at a time. In addition to the energy conservation capability of F.M.S., it has proven to be a powerful diagnostic tool for the Building Operations group. Significant energy savings are being realized, both in electrical energy and in steam and chilled water from the Central Utilities Plant. The interface between M. I. T.'s existing Auto-Call system and the Facilities Management System is complete and functional, with a remote alarm printer installed and operative in the M. I. T. Safety Office.

The overall effectiveness of energy conservation via all measures in fiscal year 1977 is measured by a cost avoidance of \$2,400,000 based on pre-1974 operating parameters.

Negotiations were initiated with Cambridge Steam Corporation for purchase of a section of their steam distribution system serving our facilities on East Campus.

A study was initiated towards supplying all campus energy needs on a total energy basis. This is being done with assistance from the Departments of Ocean and Nuclear Engineering.

Representatives from the Utilities Group participated on a consortium basis with other commercial and industrial energy consumers in several actions during the year aimed at achieving equity for the Institute in the pricing structure of bulk electricity and natural gas.

The Central Utility Plant took occupancy of Building 43, an old engineering research building located adjacent to the power plant building. This expands the capability of the central plant in routine operation and maintenance and is intended to be the permanent home for the central equipment of the Facilities Management System.

ARCHITECTURE, ENGINEERING AND CONSTRUCTION

Currently under construction is a 13,000 gross square foot interim animal care facility on Vassar Street between the Cyclotron (Building 44) and the Parsons Laboratory for Hydrodynamics (Building 48) with an expected completion schedule of November 1977. Also under way are renovations to Huntington Hall (10-250) as well as to the first floor of Building 10 for an Alumni Center, Exhibition Hall, and an Electric Power Systems Engineering Laboratory (E. P. S. E. L.). The Building 10 projects are scheduled for a fall completion date. Essentially complete is a 4,000 gross square-foot addition to the Cancer Research facility, within the Seeley G. Mudd Building. Also under construction in Building 31 is a major combustion research facility, an important addition to the Energy Laboratory's research program. Finally, construction is under way to relocate the outdoor athletic track as the first step in the construction of a new track, field, and game facility comprising the Henry G. Steinbrenner (Class of 1927) Stadium. The track relocation is expected to be completed in the fall.

Preliminary organizational and programming work is now under way for the planned Health Sciences/Health Services complex.

In a continuing effort to bring the arts to the campus, the Henry Moore and Tony Smith sculptures were installed, the former within the area of Killian Court and the latter sited at the west end of the campus adjacent to the Westgate residential complex.

TELECOMMUNICATIONS

The Institute avoided significant cost in toll calls, reflecting the impact of the "least cost" toll routing system put into operation during the year. The amount of "savings" of this system was offset to some extent, however, because of an increase in the number of toll calls as compared with 1975-76.

An experiment using telecopier devices on the campus ran for three months during the year. The experiment showed that slow speed facsimile is not acceptable as yet as a telecommunications device, particularly for on-campus transmission of messages and/or between points of short distances.

Telephone service rates continue upward as a consequence of price increases. More of such increases are anticipated.

ADMINISTRATIVE AND SUPPORT SERVICES

The Institute's Information Processing Services have now assumed the responsibility for the Department's data processing functions. These include programming, system improvements, and production runs, functions previously handled by the Physical Plant Department.

During the year, an evening shift made up primarily of heating and ventilation personnel was instituted to perform preventive maintenance tasks on the building mechanical systems.

A modified campus-wide cleaning schedule was started during the year. This is a program whereby general offices and laboratories are cleaned every other day versus daily. Daily cleaning service has been maintained, however, for classrooms, patient areas, food service areas, and public areas. Special arrangements are also in effect for biological research laboratories for health and safety reasons. This system has proven effective while maintaining a satisfactory degree of cleanliness throughout the campus buildings.

PLANNING OFFICE

During the past year, the Planning Office has devoted major energies to the support of the planning needs of the M.I.T. Leadership Campaign. These activities have included the further development of the pilot plan and design criteria for the East Campus area, and the preparation of planning and fund raising materials for new programs. In addition, the planning staff has continued to monitor Cambridge planning and development activities and has provided technical and analytical assistance on community planning issues.

The East Campus Plan

The development of a pilot, illustrative, site plan for East Campus was completed this year in time to provide site opportunities for several major projects. The development of planning criteria for the design stage of the East Campus plan is now complete and will provide the foundation on which the final designs are prepared. A number of special aspects of the planning for East Campus should be noted, however. One of the principal concerns is that not all of the property in this area is under the Institute's control and therefore situations are created where

less than optimal building site choices may have to be made. Another concern relates to the development decisions that are now moving forward in the Kendall Square project immediately adjacent to the East Campus. A number of key public circulation and transportation decisions will be made shortly that will substantially influence the organization of the Institute's physical growth in this area.

Planning for Development Activities

In support of the Development Campaign, planning assistance has been given to a number of projects:

Health Sciences and Services. One of the principal efforts has been the Health Sciences and Services Building project. Site studies, visual material, cost projections, program definition, and other information have been developed. This project is the largest to be undertaken by the Institute since 1916 and will be a keystone in the development of the East Campus.

Arts Facilities. The Arts Facilities project that has been under discussion for some time moved forward this year. In cooperation with the Council for the Arts, site studies, visual materials, cost projections, and program evaluations have been prepared to support proposals that seek capital funds for these activities.

The Sloan School. The School has put together its plan for program development and expansion. The Planning Office prepared a number of preliminary physical development alternatives to meet the School's short- and long-range planning needs. We expect these efforts to continue into the next academic year.

The School of Architecture and Planning. The Planning Office continued to support the School's need for identifying space opportunities and the development of a plan to meet both short- as well as long-term space requirements. The preparation of a fund raising document to catalogue the School's needs is now in preparation.

The Bitter National Magnet Laboratory and the Plasma Fusion Center

The rapid growth of the National Magnet Laboratory and the substantial growth expected in the Plasma Fusion Center have stimulated a great deal of planning activity this year. The limitations of existing space were clearly a hindrance on the proper development of these laboratories. The Planning Office and the Treasurer's Office have worked together to explore the possibilities of acquiring an adjacent building to accommodate the major growth expected in the Alcatraz projects that have been undertaken by the Plasma Fusion Center. This effort has now been concluded successfully and the growth of these activities will be possible within the expected time frame.

Planning for the Handicapped

National concern for the rights of the handicapped was embodied in national legislation and regulations this year. The development of the M.I.T. Guide for the Handicapped and the campus and city maps for the blind by the Planning Office in years past have proven valuable in meeting some of the obligations set forth in the new regulations. Our efforts in this area, however, are continuing. A reinventory of the Institute's facilities has been completed and the analysis and revised action plan will be completed in fall, 1977.

Transportation Planning

Our continuing efforts to improve access to the Institute, reduce the use of single occupant automobiles, and expand the use of public transportation resulted this year in the implementation of a car pool program, the introduction of a sticker fee to reduce the extra costs of administering parking programs, and the introduction of the MBTA pass plan, which permits employees to purchase MBTA bus and subway passes on campus. During the next academic year our transportation planning will include continuing to explore the development of a van pool program and the development of recommendations for the future.

Emerging Planning Issues

As progress is realized in the Leadership Campaign, a number of planning issues begin to emerge. The expansion of programs in energy, health, the arts, and food, to mention a few, will use a major part of the space and land inventory that has been painfully assembled over the last 15 years. Our student housing program still operates at the margin and even minimal growth in our student enrollment precipitates problems usually solved by crowding or other makeshift methods. This situation extends to a number of other support services that are affected by the general growth of activities on the campus. Parking is one in particular that has an immediate impact. Against these additional demands new resources of all kinds will be required.

As we focus on campus issues that are emerging as a result of growth and change, we are conscious also of the impact our presence and growth have on the City of Cambridge. The City is in a period, as are most older cities, of greater demands for services, high operating costs, need for renewal of capital plant, and confused signals as to its view of the future. The climate for development in Cambridge is always questionable given the diverse objectives expressed within the community.

In its published preliminary report on goals for the City, the Planning and Development Department has included a number of concerns relating to institutions in Cambridge, and the need to further restrict their development and expansion. While it is hard to place a judgment on the quality of these concerns, one cannot be cavalier in assuming that the public may not play a stronger role than it has in the past relative to the expansion of educational institutions. The examples in DNA research and the health industry are now too vivid to ignore as possible precedents. Fortunately, there are some signs that the mood for development in Cambridge has changed. The City has now begun to market the Kendall Square urban renewal project land and there is some reason to believe that this project may move forward in the next years. In addition, the extension of the Red Line through Cambridge and out to Arlington Heights is in the detailed design stages. The Institute stands at some point to make a significant contribution to the City in the redevelopment of the former Simplex property, located northwest of the campus. The proper development of these properties could help compensate for the removal of taxable land needed for academic purposes in other parts of the campus.

EPSCO/Draper Laboratory

While many of our planning activities involve expansion of programs and facilities, we would note one exception. For a number of years, the Institute has rented the EPSCO property on Massachusetts Avenue to house various Draper Laboratory, space research, and administrative activities. With the departure of the Draper Laboratory to its new quarters and the reduction in the level of activity of several other of the buildings' occupants, it was appropriate to reappraise the utility of continued rental of this property. Studies have been under way that describe the possible relocation of the remaining activities, and the timing and cost of such relocation. While not yet complete, the studies show that it may be possible to accommodate the activities now in rented space to other M. I. T. property.

HOUSING AND FOOD SERVICES

This past year was characterized by a number of changes in personnel. We were saddened by the untimely death of Joseph F. Lynch, Assistant Director, Housing, a long-time employee of the Institute who was especially well known for his interest in people. Dexter J. Kamilewicz, Assistant Director, Housing, left the Institute to become Managing Director of the Boston Rental Housing Association. John Woodbury was promoted to replace him. Four persons retired from the Department. They included Robert J. Radocchia, who had been associated with the food service at Walker Memorial for 28 years, and Sherman Mittell, Manager of Eastgate. Howard Markowitz left the Department to take another assignment at the Institute.

Emphasis continued this year on professional development and training for the Department. In Food Services, four staff members participated in national programs, and two in regional programs. Other personnel attended several regional or trade seminars. In Housing, emphasis was given to financial management and control. Working in teams with a member of the central office staff, the House Managers developed the budgets for their houses and were responsible for monitoring performance throughout the year. A number of people from the Department have been selected for M. I. T. 's Administrative Development Program.

The Food Services operate in a particularly dynamic environment, and considerable emphasis was given to merchandising and sensitivity to the needs and desires of our customers. A variety of new menu items was introduced including a program of vegetarian entrees in Walker Memorial and the Student Center. The two contract houses received particular attention this year, resulting in a commitment to an experimental dining program in Baker House designed to increase participation and develop a long-term plan for the residence system.

Continued upgrading of our facilities was carried out through the completion of a number of major maintenance and renovation projects. The major one was the restoration of Bexley Hall, which consisted of replacement of the mechanical systems, renovation of the kitchen and bathroom areas, and upgrading of the living space as well as the structure itself. Other projects included replacement of the roof, terrace, and garden at Baker House; renovation of the heating systems at Eastgate and Westgate; renovation to the Macomber Room in Ashdown House; and replacement of corridor carpet in East Campus.

With the assistance of the Safety Office, work continued toward a housing system which has total fire sprinkler protection. This past year we expanded the sprinkler systems in East Campus, Eastgate, and Tang Residence Hall so that all of our residence buildings now have sprinklers in the most critical areas, and many of them are totally protected by sprinklers.

Several projects begun this past year will continue into the next. We expect to remodel Pritchett Lounge and upgrade the kitchen equipment in Walker Memorial and the Student Center. This coming fall, Random Hall will be opened as a dormitory to help relieve the anticipated overcrowding in existing housing. Extensive structural restoration of the East Campus dormitories has begun and will continue during the coming year.

CAMPUS PATROL

For the first time in several years, it is possible to report a decline in almost all categories of activity processed by the Campus Patrol, beginning with a decrease in the number of recorded complaints handled by the Department. The total of 1,906 constitutes a drop of 11.7 percent from last year.

The most important area, crimes against persons, showed little change. There were no reported rapes on campus within the 30 incidents involving crimes against persons. Service calls rose by almost 2,000 to 8,068 for the year. This total includes a great many night escort service calls and lockout calls.

Dormitory thefts dropped slightly and the theft of Institute property showed a small increase to bring our annual loss total to \$67,000, the highest in recent years. Emphasis is being placed on our "Bolt Down" program as a major portion of this loss was in stolen typewriters.

The Institute's "open 24 hours a day" policy necessitates the continuation of our crime prevention program efforts on a regular basis. Among other things, this involves a door-to-door canvass of all Institute buildings seeking the cooperation of all persons through education and awareness. During routine patrol periods, Campus Patrol Officers issued more than 1,300 crime prevention notices calling attention to lax conditions, open and unattended areas, the source of much of the problem.

In other important areas the records indicate 108 motor vehicles stolen from the M.I.T. area, a drop of 44 percent over the past year. One hundred five bicycles were stolen, which is slightly lower than the previous year. Over \$28,000 in property was recovered during the year.

The emergency ambulance service continues to provide comprehensive service to the community in handling 1,653 calls during 1976, an increase of 337 calls over the past year. Sixty percent of all calls involved service to students. We are engaged in fulfilling emergency medical technician training for our personnel, and currently 12 officers are certified.

The overall in-service training programs under the direction of the Supervisor of Training continue to provide the Department with the level of professionalism which is required for it to fulfill its mission.

The administration and control of parking under the direction of the Institute Parking Committee is implemented on a day-to-day basis by this Department. For the first time, an administrative handling fee of \$5 per parking sticker was implemented to offset the growing cost of this system. New and improved regulations were instituted with firm, consistent, enforcement procedures employed in order to deal with the ever-increasing demand for parking.

As an integral part of its operation, the Campus Patrol continues to support on an everyday basis other Institute groups such as the Office of the Dean for Student Affairs; the Medical Department including the Social Service, Psychiatry Service, and Medical Emergency Service; the Safety Office; the Housing Office; and the Physical Plant Department; as well as carrying out necessary liaison with outside agencies. Openly appreciated is Campus Patrol support given to Institute personnel through assistance with their varied and sometimes extraordinary problems. This constitutes a unique behind-the-scenes service that would be difficult to replace.

SAFETY OFFICE

The year was highlighted by M.I.T.'s receiving the National Safety Council Award of Honor in the National College and University Awards Program. This is the highest honor awarded. Colleges and universities are evaluated against benchmark standards developed by the National Safety Council.

The M.I.T. Accident Prevention Guide was completed this year. The last two sections were published and distributed. This has been a major undertaking of the office and has spanned a three-year period. Considerable interest in the guide has been shown by other universities.

Vice President, Operations

As part of a review connected with the DNA experimentation controversy, a review of the Institute's Safety Committee structure was undertaken. This has resulted in the formation of a Council for Environmental Health and Safety which unifies the management structure of health and safety for better coordination and communication.

Laboratory Safety

Several electrical shock accidents, principally involving lasers, have precipitated increased surveillance of the non-commercial type laser units. Evaluation of the present laser safety program is under way.

A P3 laboratory was established at the Center for Cancer Research, and the Safety Office coordinated establishment of the Emergency Response Procedures effort connected therewith.

Chemical waste volume remained the same as last year through December. The addition of a full-time employee whose duties include waste pickup has resulted in a 10 percent to 15 percent increase since January.

Two members of the Safety Office took a three-day National Cancer Institute course in biohazards at Massachusetts General Hospital.

Educational activities included 13 first-aid courses given to 121 persons, nine demonstration sessions on cardiac pulmonary resuscitation given to 119 persons, and a spill control seminar for Institute Safety Coordinators reviewing how to handle a fairly small-scale hazardous chemical spill.

Fire Protection

Fire alarm testing in the dormitory system has been placed on a regularly scheduled program basis.

Much work was done with the fraternities this year. Physical facilities evaluations are continuing. A seminar on fire safety was conducted by the Safety Office.

The number of fires we have had over the last few years has trended downward and is leveling off. Sprinkler actuations are increasing, probably due to the significant increase in the number of sprinkler heads being installed.

Industrial Safety

The industrial accident rate, measured in terms of the number of compensable injuries per 100 employees per year, continues to remain below two injuries per year. There appears to be some stability in this figure over the last eight years. The cost of these injuries has been rising gradually over these past years, due to inflation and increased medical costs. This year, the number of severe injuries was significant enough to raise the cost considerably.

A greater effort will be made in the coming year to deal with the Physical Plant employee accident program which influences our accident record greatly. A number of new programs have been initiated this past year. Among them are: training sessions for shipping and receiving personnel on how to handle hazardous chemicals; a safe battery maintenance program for building services personnel using the large floor polishers at night; survey of extension cords stocked by Physical Plant for adequacy of grounding system. This was made possible by the purchase of an electrical analyzer. Electrical equipment and appliances also have been checked.

There were no visits to the campus this year from the Occupational Safety and Health Administration (OSHA), although the Linear Accelerator in Middleton was the object of a surprise OSHA-type inspection conducted by the Energy Research and Development Administration.

GRAPHIC ARTS

The most significant development in the Graphic Arts Service during fiscal year 1977 involved the Institute's decision to purchase 17 high-speed Xerox copy machines and to place them in high-volume locations around the campus. This was the beginning of a program designed to effect cost savings, improve efficiency, and to avoid duplication of copying machines. Graphic Arts was designated to be responsible for overseeing the acquisitions and the subsequent administration of this important program.

To help organize and implement this plan, Glenn Curtis was transferred to Graphic Arts from the Purchasing Department. In addition to his new duties, he continues to be responsible for purchasing printing, copying, and related supplies.

It is satisfying to report that revenue in the Graphic Arts Service increased by approximately 10 percent over the previous year. This is significant in light of the five percent drop-off reported for fiscal year 1976 and the continuing budget restrictions at the Institute. By department, the increases were fairly consistent at 10 percent, with only the Photographic Section experiencing a decline. Especially encouraging is the increased use of the Offset Printing Section, even though volume at the four Copy Centers continues to increase at an even more accelerated rate. Helping considerably at the main Copy Center was the use for the first time of self-service copy units. Two machines for this purpose were purchased during the year and the addition of a third is imminent. Other new equipment purchases included a faster, more sophisticated typesetting machine with memory capabilities in the Illustration Department, and a faster, more diversified addressing/labeling unit in the Mailing Section.

ENDICOTT HOUSE

This past year shows a modest drop in the dollar volume of activity as compared to the "banner year" of 1975-76.

The house was open 12 months of the year, but was used 240 days and 162 nights as against 288 days and 223 nights during the prior year. Although the number of both resident and nonresident groups increased in 1976-77, the numbers in the groups decreased. Many groups consisted of 12-15 persons, and, in the case of resident conferences, stayed fewer days on the average. This resulted in a decrease in occupancy figures and number of meals served. Another major factor in the drop of occupancy figures was the cancellation of the Sloan School of Management Urban Executive Program. The group is normally housed at Endicott House for four weeks in June, but was housed on campus this past year. In addition, several other conferences were cancelled for various reasons. The extra use by small groups could not compensate for the loss of a group of 28 persons staying a week or a month. M.I.T. use of the house, however, both for resident conferences and for nonresident meetings, increased somewhat.

Twenty-three resident conferences were held during the year. The total of 4,247 overnights gave us an average of 26.2 guests per night. Ninety-seven nonresident groups, with a total of 6,165 guests,

Vice President, Operations

used the house during the year. Meals served during the year totaled 18,526, averaging 77.1 meals per day of operation.

Major capital and maintenance projects completed during the year included installation of a new underground lighting and power feeder to the main house; extension of the sprinkler and safety systems; refinishing of most of the wooden floors; installation of a drainage system around the lower parking lot; major tree work; and the purchase of several needed items of grounds equipment.

The furnishings program progressed well. During the year, the draperies and cornices on the main floor landing were replaced; the couches in the Gun Room were reupholstered; tables and chairs in the Gun Room and Conference Room and chairs in the dining rooms were repaired. On the bedroom floors, a number of bedspreads and draperies were replaced; armchairs and desk chairs were reupholstered; carpets were replaced; and new lamps and bedside tables were purchased.

Although we did not increase our rates this past year, it will be necessary to increase them slightly, effective July 1, 1977, in order to meet increased costs of operation.

PHILIP A. STODDARD

Vice President, Research

This has been another year marked by changes and contrasts.

The Research Laboratory of Electronics has been approved by the Joint Services for three-year funding. Support level increased 11 percent over the preceding year.

The Energy Laboratory successfully negotiated with the Energy Research and Development Administration an institutional contract which has considerably facilitated the funding of new projects. Private support has continued at an encouraging level. Gross support amounting to \$5,957,000 is eight percent over the previous year and rapid growth is anticipated for several more years. The growth is being encouraged by investments in new combustion laboratory facilities.

Dr. Otto Harling came to M. I. T. from Battelle Northwest Laboratories to be the Director of the Nuclear Reactor Laboratory on July 1, 1976. The reactor became operable at its rated level of five megawatts on December 1, 1976 after being shut down since 1974 for modification.

Professor Nicholas J. Grant retired as Director of the Center for Materials Science and Engineering after nine years of devoted service. He is succeeded by Professor Mildred S. Dresselhaus who is well known for her researches in solid-state materials.

The Laboratory for Nuclear Science rebounded from a less-than-inflation four percent growth in funds in 1975-76 to 15 percent growth in this past year.

The Francis Bitter National Magnet Laboratory showed growth of 52 percent, largely attributable to the ALCATOR fusion project and to growing interest in superconducting magnets. Support for the Center for Space Research declined somewhat in variable dollars, and hardware involvement continued to decline in favor of data reduction, comparison with theory, and analytical studies.

Taken as a whole, the year has been a good one and a high level of momentum indicates that 1977-78 will also be a good year.

The reports that follow outline accomplishments and new directions.

THOMAS F. JONES

Francis Bitter National Magnet Laboratory

Shortly after the founding of the Laboratory in 1960, when the new high field superconducting materials were first being studied, members of the Laboratory's staff discussed the feasibility of combining the water-cooled, high field Bitter magnets with large superconducting magnets to create higher continuous magnetic fields. For a number of years, the Laboratory's Bitter magnets have been providing fields up to 230 kilogauss, the highest continuous fields available anywhere. A hybrid magnet consisting of a superconducting outer section and a water-cooled inner section was completed and tested to 254 kilogauss in the early spring. The construction of this magnet was financed by the Katholieke Universiteit of Nijmegen, The Netherlands and will be shipped to them in the coming year. In June, under National Science Foundation sponsorship, using the outer section of this hybrid magnet and a more powerful inner section, the Laboratory's Magnet Research and Development Group produced a new record continuous field of 300 kG. These new higher fields are certain to open new vistas in basic research in the physics of solids and plasmas and in many other fields of science. Thus, the dreams and ideas of the early 1960s have become realities in the middle 1970s.

Another highlight of the year was the operation of the ALCATOR high magnetic field tokamak at record-high values of density-confinement time product (2×10^{13} sec/cm³). This is within a factor of 10 of the value required for ignition of a thermonuclear reaction. A larger machine, ALCATOR-C, scheduled for operation in 1978, is expected to produce density-confinement time values at or near the ignition value. While plasma temperatures in both machines are a factor of 10 below ignition temperatures, these high field tokamaks are leading elements of the nation's effort to develop a thermonuclear energy capability.

A study of a practical energy-producing tokamak reactor design characterized by high magnetic field, small size, and high fusion power density is under way. A novel superconducting magnet configuration conceived here is a central feature of this proposed reactor.

The Laboratory is engaged in a major program of development of superconducting magnets for magnetohydrodynamic (MHD) electric generators. The multiyear program involves research and development of concepts suitable for the 2,000 ton magnets ultimately needed for base-load MHD generators, as well as technical management of near-term magnet procurements for the national MHD program. During this first year of the program, research has been conducted on a number of related aspects of the behavior of superconductors, and a large superconductor testing facility has been completed.

A program for the development of 150 kilogauss superconducting materials has been funded by the Energy Research and Development Administration (ERDA). This is a long-term program for development of materials for possible applications to large high-field thermonuclear and MHD devices and is a joint program involving the Laboratory and the Center for Materials Science and Engineering.

A highly successful NATO Advanced Study Institute on applications of superconductivity was organized in Italy last summer by Laboratory staff members. The resulting proceedings give an up-to-date review of many applications of superconductors.

A very appealing linear-chain model has been proposed to describe the properties of high temperature β -W structure superconductors. This model suggests that the upper critical

field of such materials in the tetragonal phase should show a large anisotropy. Measurements of the upper critical field to 230 kilogauss in single crystal Nb_3Sn and V_3Si as a function of crystallographic orientation show a small anisotropy. Higher field measurements are planned.

Basic properties of superconductors in very high magnetic fields have been studied in ultrathin (100 Å) cryogenically deposited films. This technique allows the effects of orbital depairing, spin paramagnetism, spin-orbit scattering, and thermodynamic fluctuations to be quantitatively compared with theories of the behavior of superconductors in high magnetic fields. Tunneling measurements with spin-polarized electrons have been made on Gd, Dy, and other rare-earth metals. In all cases, the polarization of the tunneling electrons is predominantly in the majority spin direction and appears to be a measure of the spin polarization of the conduction electrons.

Magnetic studies of solids under high hydrostatic pressures and high magnetic fields have been completed on the RSb series, where $R = \text{Pr, Gd, Tb, Dy, Ho, Er, or Tm}$. The change in ordering temperature, T_N , with pressure shows no simple systematic trends in contrast with observations of the variation of T_N with lattice parameter obtained by chemical substitution of rare earth atoms.

Multicritical points in antiferromagnets which closely approximate several theoretical models have been investigated in magnetic fields up to 180 kilogauss. The boundaries which separate the various magnetic phases were determined with high precision from ultrasonic and thermal expansion data. The results confirm the striking new theoretical predictions which are based on scaling and renormalization-group analysis.

Mössbauer spectroscopy of the iron-sulfur protein active site synthetic analogs has been extended to the analogs of the reduced state of bacterial ferredoxins. These materials, formally $(\text{Et}_4\text{N})_3 [\text{Fe}_4\text{S}_4(\text{SPh})_4]$, exhibit multiple iron subsites and an unusual intracuster antiferromagnetic spin arrangement at low temperature. These results demonstrate that the subsite inequivalence in the proteins is due to interactions in the $[\text{Fe}_4\text{S}_4(\text{SPh})_4]$ cluster and not to constraints imposed by the protein chain. Mössbauer spectroscopy has also been used to observe iron deposits in the heart tissue of victims of the blood disease, thallossemia. The iron is deposited as hemosidein, a well-known iron storage protein. Measurements of the temperature dependence of the hyperfine spectrum have been analyzed to yield an average value of 70 Å for the size of the hemosidein grains.

Theoretical investigation of the asymmetric lineshapes observed here in CO_2 laser excitation studies of Rydberg states in helium has revealed that the asymmetry is caused by the motional Stark effect in a magnetic field and has shown how to use the observed lineshapes for determining natural line widths and accurate line centers of the atomic transitions involved. Another new principle has been proposed for doing Doppler-free spectroscopy in high magnetic fields, using crossed electric and magnetic fields to cancel out the first order Doppler shift of the atomic or molecular transitions of interest.

In the nonlinear 4-photon mixing of high power CO_2 laser beams in germanium at room temperature, intense infrared radiation pulses with peak power as high as 0.5 MW have been generated successfully in the 8.6 μm region with 1.5 percent conversion efficiency. Theory predicts that much higher output power and efficiency are possible. This 4-photon mixing scheme which has the potential of producing thousands of discrete frequencies in the 9-13 μm region, will find important applications in laser photochemistry.

The Laser-Plasma Group has made several important contributions in studies of the effects of magnetic fields on interactions of high-power pulsed CO_2 laser radiation with plasmas. Laser-induced damage to solid surfaces was found to be greatly reduced when a magnetic

field is applied in the target region. When a field of 30 kilogauss or more is applied, a partially confined plasma is formed in front of the surface and heated to more than one million degrees. The mass loss from the solid itself can be reduced by twenty-fold over the zero-field case. The effect of strong magnetic fields on the backscattering of laser radiation from plasmas was studied. A field perpendicular to the direction of laser propagation reduces the intensity of backscattering from plasma acoustic waves. Light hydrogen ions are considerably more influenced by the field than heavier helium ions. These magnetic effects in laser-heated plasmas may have important implications for laser fusion research, where the influence of magnetic fields is just beginning to be appreciated.

The nuclear magnetic resonance (NMR) facility for biomolecular research located at the Laboratory has attained full-scale operation during the past year and is being used intensively by biomedical research workers. One of the research highlights of the past year was the confirmation by Professor R. B. Woodward of Harvard University that his synthetically produced Vitamin B₁₂ was identical to material from natural sources. His confirmatory proton NMR experiments, carried out at 270 MHz under high resolution conditions, were the culmination of a long and complex synthesis project which required 10 years and the collaboration of 100 fellow scientists to accomplish. In other exciting experiments using phosphorous NMR at 109 MHz, it has been possible to observe the time course of metabolic processes in excised rat heart kept alive in an NMR sample tube by perfusion. Variations in the concentrations of metabolites could readily be followed over a cycle where a state of anoxia was produced after which the heart was reperfused and brought back to a functioning state.

Two new low magnetic field studies of the human body have been initiated. The first is an attempt to determine whether early detection of breast tumors is possible by magnetic measurements. In the second, the body was found to be rich in steady magnetic fields arising from steady currents in skeletal muscle.

Significant progress has been made in the development of a high gradient magnetic separation technique for removing impurities from coal. Tests here have shown that substantially all of the inorganic sulfur and 40 percent of the ash-forming materials are removed from samples of liquefied coal.

BENJAMIN LAX

Center for Materials Science and Engineering (C.M.S.E.)

The Center for Materials Science and Engineering is housed in Building 13, the Vannevar Bush Building.

The aims of C.M.S.E. are to initiate, encourage, fund, and coordinate interdisciplinary research in materials, based largely on core funding by the National Science Foundation (NSF) and further supported by small block funding and individual grants to faculty members. Such additional support may be through other government agencies, industry, fellowships, and M.I.T. itself.

A total of about 35 faculty are supported under the NSF-Materials Research Laboratory program with about 100 graduate students, visiting professors and scientists, and other staff. In total more than 45 faculty participate in C.M.S.E. programs. C.M.S.E. makes it a practice to provide research funding of the high-risk SEED type as well as funding for new faculty first arriving at M.I.T.

Faculty, staff, and students of the Departments of Chemistry, Chemical Engineering, Electrical Engineering and Computer Science, Materials Science and Engineering, Mechanical Engineering, and Physics participate in C. M. S. E. programs.

In addition to support of research, C. M. S. E. initiates and maintains an impressive group of Central (Service) Facilities in support of materials research throughout the Institute. Supervised by faculty members, the facilities provide special materials in special forms, characterization and analytical services, testing laboratories, and a machine shop. C. M. S. E. is equipped with the latest and best equipment and instrumentation in most instances and tries to maintain a leading position in such services in all instances.

The NSF core funded program supports research in five major areas, each area staffed by faculty from several departments with common interests in that particular area of thrust. These areas are: I Deformation and Fracture, with Emphasis on Temperature and Strain Rate Effects; II Materials Processing, with Emphasis on Structure and Property Studies of Rapidly Quenched Materials; III Surfaces, with Emphasis on Catalytic Materials and Catalysis; IV Electron Optics; and V Phase Transitions.

Some highlights of research, abbreviated, are given below as examples of the types of studies which are supported under each area of thrust. Many programs are the result of close collaboration among several faculty from several departments. For a more complete view of research in materials, the reader is referred to the Annual Report on Research in Materials at M. I. T., a publication which is compiled and issued internationally by C. M. S. E.

Highlights for Area of Thrust I

Creep strengthening with oxide dispersion in grain boundaries. It is widely accepted that high temperature, close-packed (face-centered cubic) alloys are stronger than body-centered structures of similar classes of alloy (austenitic steels versus ferritic steels). This is attributed to higher diffusion rates in the BCC lattice and no exceptions have appeared in the literature. Accordingly it is of extreme interest that Gregory Hildeman and Professor Nicholas J. Grant have found that Fe-BeO, an oxide dispersed iron alloy, containing about 3 volume percent of very finely dispersed BeO, is stronger by a factor of 1 1/2 to 2 at 700°C and 815°C, respectively, than even austenitic stainless steels, and far stronger than any conventional ferritic steel (including the stainless grades). The fine dispersion of BeO particles in the cold worked matrix presents a structure highly resistant to high temperature deformation, primarily grain boundary shear, but including granular slip. The reduction of grain boundary shear makes it necessary for the structure to deform more extensively by normal slip processes, resulting in enhanced creep resistance and delaying the fracture processes. It will be interesting to see if more highly alloyed ferritic steels can be made to show significant improvement over the pure iron-base alloy and to determine the temperature range over which high temperature deformation is enhanced. Since conventional, ferritic iron-base alloys require large additions of expensive alloying elements to achieve the austenitic FCC structure, the development of inexpensive ferritic BCC alloys by oxide dispersion (OD) techniques is especially attractive. The use of SEM and TEM in the C. M. S. E. Central Facilities was essential to verify the very fine structures and the increased hardening action of these OD alloys. The help of Professor John B. Vander Sande was vital for the success of this study.

Interfacial compounds on glass fibers. Professor Donald R. Uhlmann and Tina Kritchevsky have found that the usual commercial water quenching of glass fibers initiates the formation of islands of a "corrosion" layer. These islands grow into a smooth corrosion layer which had previously been taken as the surface of the fiber. When the fiber is coated with a coupling agent, some of the agent is incorporated into the corrosion layer. Under tension, cracks

develop not only in the coating layer but also in some cases in the underlying corrosion layer parallel to the fiber axis. Discussions with Professor Frank A. McClintock showed how thermal stress could lead to the observed fracture modes, but only if the layer is anisotropic. If the forming of such a corrosion layer cannot be avoided during quenching and coating, one must be concerned with the bonding of the corrosion layer to the core of the fiber as well as with the bonding of the coupling agent to the resin matrix.

The implications of these findings are important enough that a detailed examination of the standard commercial processes for making fiber glass seems called for, and the largest US manufacturer of fiber glass has indicated that the results may provide a basis for significant changes in their processes. Meanwhile, Auger studies are being made with the aid of the Central Facilities and in consultation with Professor Morris Cohen to determine the composition of the layer.

Observations of Precipitate-dislocation interactions with 20 Å resolution. Professor Vander Sande has successfully used the weak-beam technique in electron-microscopy in a detailed study of heterogeneous precipitation on dislocations. Even in a system where the precipitate size and density is small, it is possible, when using weak-beam microscopy, to uniquely identify the "catalyzing" dislocations. In the early stages of precipitation it is possible to observe precipitates on or near dislocations even when their size is still only 1 - 20 Å. In addition, the configuration of the dislocation and the precipitate can be unambiguously observed. This area of research has previously been one of the most difficult for electron microscopy because of image overlap in normal bright field microscopy.

Applying these techniques to alloys deformed to various stages in a Bauschinger loop should provide important insights into the role of various particles as dislocation obstacles. These techniques will be of great help in designing alloys and heat treatments for improved behavior and in putting the plastic flow relations on a more physical basis, as is being done by Professor McClintock.

Highlights for Area of Thrust II

Dr. J. Megusar, working with Professors Grant and Ali S. Argon, has been examining the role of strain rate on the mechanical behavior of amorphous $\text{Pd}_{80}\text{Si}_{20}$. While it is generally expected that metallic glasses should show a strain rate effect with respect to strength and deformation, the behavior has not previously been studied in detail. This alloy, with a glass transition temperature near 300°C, fails in an apparently brittle mode at room temperature regardless of the applied strain rate. The fracture stress is near 200,000 psi. In tests at 250°C, at strain rates varying from 0.2 to 0.0002 min^{-1} , only the highest strain rate results in a relatively brittle behavior. As the strain rate decreases, the material deforms up to 14 percent at 0.0002 min^{-1} ; obviously the plastic resistance of the glass has decreased markedly. In fact the strain rate effect, on a smaller scale, was observed at 120°C. These observations are of great interest in enhancing our understanding of the applications of metallic glass to structural uses. Of importance is the (unfortunate) large decrease in strength of the alloy at the slowest strain rates, which is as large as 75 percent at 250°C, where the alloy becomes very strain-rate sensitive. Professor Argon is collaborating in these studies to furnish comparisons with the ideal plastic flow behavior of inorganic and organic glasses, as well as to help with the mechanics of flow localization. Reliance on the SEM and TEM facilities is critical to this program.

A theoretical model for the electronic structure of amorphous Cu-Zr alloys, based on SCF-X α molecular-orbital calculations for representative Cu-Zr clusters, has been constructed by Professor Keith H. Johnson. This model is novel because it focuses on the fundamental roles of short-range order, localized electronic structure, and the formation of directed

chemical bonds in stabilizing the glassy metallic state. In particular, the effective transfer of electrons from the Zr orbitals to Cu orbitals at the Fermi level gives each Zr atom a formal non-zero oxidation number of valence state, such charge transfer being consistent with the difference in electronegativities of zirconium and copper. Those remaining Zr orbitals not involved in the local bonding with Cu atoms are in the proper valence state to overlap and hybridize with similar orbitals on neighboring Zr atoms, thereby promoting the formation of Zr-Zr bonds.

Highlights for Area of Thrust III

A major highlight of the experimental and theoretical work carried out thus far in Area III is the discovery that concepts of coordination chemistry, such as that of "coordinative saturation," long familiar to the practicing chemist and important to the understanding of homogeneous catalysis by transition-metal coordination complexes, seem also to be key to the understanding and possibly the control of heterogeneous catalytic activity and selectivity on transition-metal surfaces. For example, Professor George M. Whitesides has discovered that, by transferring oriented mono- and multilayer films of unsaturated fatty acids to the surfaces of platinum foils, the rate of catalytic hydrogenation of double bonds can be significantly altered. These effects are dependent on film pressure and subphase composition. The results can be interpreted in terms of the coordinative saturation of platinum surface atoms by the molecular components of the organic film and the influence, both steric and electronic, of such coordination on the active sites of catalytic reactivity. On the theoretical side, Professor Johnson has carried out SCF-X α electronic-structure calculations for coordinatively unsaturated and coordinatively saturated platinum complexes which are models for active sites and chemisorbed hydrogenation reaction intermediates on platinum surfaces. The results suggest that coordinative unsaturation of a platinum site leads to a significant reduction in the energy and effective electronegativity of the highest occupied Pt d-orbital (as compared with the atomic and coordinatively saturated bulk limits). This enhances symmetry-conserving overlap of and electron flow between this orbital and the unoccupied antibonding σ_u orbital of H₂ and π^* orbital of hydrocarbons such as C₂H₄ and C₂H₂, thereby promoting the dissociation and reactivity of H₂ with such hydrocarbons. These results are consistent with the observations of Professor Whitesides that coordinative saturation of a platinum surface by organic films can alter hydrogenation activity, and they provide a novel explanation of how coordinatively unsaturated sites (including "steps") on a platinum surface or particle can be active centers for the dissociation and catalytic reactivity of H₂. Preliminary SCF-X α results for models of platinum (and ruthenium) dispersed on oxide supports such as alumina and silica suggest that the coordinatively unsaturated bonding of metal atoms at the oxide-metal interface can, in analogy to the complexes described above, result in significantly altered electronic states (and thus possibly altered catalytic activity) of the metal, as compared with the same metal in the atomic and bulk crystalline limits. Finally, Professor Johnson has made progress in developing a quantitative molecular-orbital theory of catalytic reactivity, based on the correlation of spin-orbital electronegativities and symmetries of the catalyst-reactant system. This theoretical approach will be further developed and applied in ongoing studies in Area of Thrust III.

Highlights for Area of Thrust IV

Highlights of the lead salt program. Center funds have for several years provided direct and indirect support for a lead-salt program that involved the collaborative participation of Professors Stephen D. Senturia, David Adler, George W. Pratt, Clifton G. Fonstad, and Marc A. Kastner, and their students. This program is an excellent example of the benefits of collaborative research which led to significant contributions both in extending our fundamental understanding of narrow band-gap semiconductors and in providing answers to applications oriented questions concerning the performance of double heterojunction laser diodes.

Now concluded, this program has yielded, during the past year, a result of major importance which ties together many features of the earlier work. A new model (Michael Kim, Professor Senturia) based on a many-body formulation of electron-phonon interactions has permitted the calculation of an RPA electronic dielectric function for $\text{Pb}_{1-x}\text{Sn}_x\text{Te}$ and the evaluation of electron renormalization energies due to coupling between phonons and the electron-hole excitation. The dielectric function provides detailed understanding of the transport coefficients in the narrow-gap regime, while the electron renormalization, which leads to major modifications to the Dimmock-Melngailis-Strauss band-crossing model, accounts for the Knight shift and energy gap anomalies previously discovered by Professor Senturia's students.

Professor Fonstad's work, on double heterostructure lead-salt diode lasers, has resulted in the publication of an analysis of laser transient response that includes, for the first time, interface recombination effects. In many cases, the recombination can be accounted for by defining an effective minority carrier lifetime that is a transcendental function of bulk lifetime, interface recombination velocity, and width of the active region.

The optical transistor. The "optical transistor," previously proposed by Professor Pratt, has been built and tested for feasibility. The transistorlike action is derived from the control of second harmonic optical power produced in a nonlinear material by an optical signal whose presence affects the phase-matching condition between the second harmonic beam and its pump. Second-harmonic radiation produced in a tellurium crystal and from a CO_2 pump was directly modulated by a signal beam from a CO laser. The differential power gain of four which was obtained was limited by aperture effects that restricted the degree of overlap between pump and signal beams. In principle, it should be possible to increase the gain by an order of magnitude. The device also lends itself to the synthesis of logic elements; to demonstrate feasibility for this class of operation, an optical inverter was built.

Characterization of electrooptic materials. Professor Cardinal Warde has developed a simple method for evaluating the spatial resolution of electrooptic materials that are intended for adaptive optical devices. The method, based on two-beam interferometry, gives an optical mapping of the integrated internal electric field produced by charges or voltages on the surface of the material. The apparatus used to make the measurements is essentially a skewed Michelson interferometer and is applicable to both hard-wired and electron-beam addressed materials.

Model for electronic structure of amorphous semiconductors. Professors Kastner and Adler, in collaboration with Professor Helmut Fritzsche of the University of Chicago, have developed a model for the electronic structure of amorphous semiconductors which accounts for the unique behavior of chalcogenide alloys in a natural way. This model suggests that transport in these materials is controlled by specific intrinsic defect centers, which are always present in relatively large densities due to the metastable nature of the materials. The model has been used to interpret the unusual luminescence results.

Professor Kastner has used a new technique, fatigue spectroscopy, to determine that excitons in amorphous As_2Se_3 diffuse large distances ($\sim 1 \mu\text{m}$). This unexpected result correlates well with the switching recovery analysis of Professor Adler on multicomponent chalcogenide glasses. Professor Adler has also completed a theoretical analysis of the electronic structure of impurities in amorphous semiconductors and has used this to interpret the recently discovered extrinsic conduction in a wide range of these materials.

A Mott-Hubbard model for the $\text{Ni}_{1-x}\text{Co}_x\text{S}_2$ system. Professors Adler and Mildred S. Dresselhaus have collaborated on an analysis of the $\text{Ni}_{1-x}\text{Co}_x\text{S}_2$ system, explaining the anomalous temperature and composition dependence of both the electrical conductivity and

thermoelectric power of this system in terms of a model in which NiS_2 is a narrow-band Mott-Hubbard insulator. As the temperature increases, electronic screening leads to a collapse of the Mott-Hubbard gap in the system, but with phonon-assisted-hopping conduction dominant on both sides of the transition.

Highlights for Area of Thrust V

Percolation in Two-Dimensional Magnets. Percolation is a problem of general interest which is relevant in a remarkable variety of disciplines, including geology, agriculture, engineering, communications, biology, and basic statistical physics. As discussed by a number of workers, perhaps the simplest percolative system is a dilute magnet with only nearest neighbor bonds. In this case, as a function of diluent concentration the phase transition temperature T_c drops continuously, until at the percolation concentration p_c one has $T_c=0$. For $p < p_c$ the system breaks up into finite clusters, and there can be no long-range order. Professor Robert J. Birgeneau and his collaborators have carried out an extensive investigation of the static and dynamic spin fluctuations in two dimensional (2-D) magnets near the percolation threshold. These experiments have yielded a variety of interesting and novel results. Firstly, the experiments suggest that the point $p = p_c$, $T = 0$ in magnets is a new type of multicritical point exhibiting "geometrical" critical behavior as a function of $p - p_c$ at $T = 0$ and thermally driven critical behavior as a function of T at $p = p_c$. Secondly, the development of correlations within the percolation clusters in the precritical region is well described by a simple no-adjustable parameter self-avoiding walk (SAW) model. Finally, they have developed a multicritical point scaling theory for the region around $p = p_c$, $T = 0$ using the SAW ansatz for the asymptotic temperature dependent correlation length.

The experiments were carried out on two samples, $\text{Rb}_2\text{Mn}_{.54}\text{Mg}_{.46}\text{F}_4$ and $\text{Rb}_2\text{Mn}_{.57}\text{Mg}_{.43}\text{F}_4$. These samples both simulate very well dilute nearest neighbor (nn) 2-D Heisenberg antiferromagnets with a weak dipolar Ising anisotropy. For the 2-D nn square lattice $p_c = 0.59$ so that both samples should remain paramagnetic down to $T = 0$. The magnetic correlation lengths were measured as a function of temperature by means of quasielastic neutron scattering. Several interesting results were found. Firstly there is no critical divergence in the correlation length. Rather, the magnetic correlation lengths in both samples saturate at $T = 0$ at values corresponding to the appropriate mean size of the percolation clusters. For $T > 4\text{K}$ the correlations follow approximately a $T^{3/4}$ law as predicted by the SAW model in two dimensions. Also it is only at low temperatures that the change in Mn^{++} concentration from 0.54 to 0.57 ($p_c = 0.59$) has a drastic effect. All of these results together lead one to the multicritical model discussed above.

Spontaneous magnetization at marginal dimensionality in LiTbF_4 . Since phase transitions in so many systems exhibit universal behavior, it must be that this behavior is determined by geometrical considerations such as the spatial dimensionality and symmetry of the order parameter rather than details of the interactions between molecules or atoms. Quantitative examination of these ideas shows that if the dimensionality of the system is high enough, classical (mean field) theory is adequate to describe the behavior. For dimensionality equal to or less than the marginal dimensionality, the renormalization group (RG) theory is required. The exact results of the RG are calculable only at the marginal dimensionality, which for most materials is four.

LiTbF_4 is an Ising ferromagnet with dipolar interactions and the anisotropy of these interactions lowers the marginal dimensionality to three; thus a stringent test of theory is possible. The prediction is for subtle logarithmic corrections to the classical theory, and very precise experiments are required to observe them. The spontaneous magnetization, for example, is predicted to vary as $M \sim t^{1/2} |\ln t/t_0|^{1/3}$ (where $t = 1-T/T_c$) near the phase transition T_c . Professor David J. Litster and his colleagues used a sensitive optical technique to observe

light scattered by magnetic domains and thus to determine the magnetization with sufficient precision to see that the RF calculations agree very well with the measurements. This verification increases our confidence in the RG theory and its predictions for other problems in phase transitions.

The experiment was possible because Dr. Arthur Linz of the Center's insulating crystal growth facility was able to provide high quality crystals of LiTbF_4 . This material is of excellent optical quality, colorless and transparent to visible light, and with large magneto-optical coefficients. It is one of a variety of materials under investigation in the Center for magneto-optical device applications.

MILDRED S. DRESSELHAUS

Center for Space Research

The year 1976-77 marked a continuing period of transition in the national space program. The change in direction toward a reduced number of larger space research and applications missions characterized by the Space Shuttle-Spacelab, Space Telescope, Earth Resources Satellites, and Space Applications Satellites, has resulted in markedly fewer new starts of science oriented missions of the type in which the Center for Space Research was liberally involved during the 1967-77 period. The impact of this change has been felt principally in a reduced involvement in the design and fabrication of new scientific payloads. On the other hand, the combined data analysis and interpretation effort from existing plasma and X-ray astronomy missions plus the new ones to be launched in 1977 and 1978 can be expected to continue the expansion already being felt in these disciplines.

Several proposals for new research starts in X-ray astronomy, plasma physics, multispectral survey of planetary surfaces, very long baseline interferometry, and infrared astronomy have been submitted to the National Aeronautics and Space Administration (NASA) for consideration.

Notable among the currently active projects is the continued high state of productivity of the Small Astronomy Satellite program under the direction of Professor George W. Clark, assisted by Professors Hale V. Bradt, Walter H. G. Lewin, Saul A. Rappaport, Claude R. Canizares, and Paul C. Joss, all of the Department of Physics. In the more than two years of its operation, SAS-3 has provided a wealth of exciting new discoveries and data which have produced an impressive list of publications. This project is expected to be fully funded for at least another year of data taking and analysis.

The acquisition of new experimental data in X-ray astronomy and interplanetary plasmas is expected to reach unprecedented levels, assuming successful launches of the High Energy Astronomical Satellites A and B in 1977 and 1978 respectively, and the Voyager Mission also in 1978.

A new program of research was recently initiated under NASA sponsorship to study the role of the vestibular system in manned space flight. Professor Laurence R. Young, Department of Aeronautics and Astronautics, is the principal investigator. The program will comprise a series of active experiments in Spacelab 1 in the 1980-81 time frame.

The SAS-3, Voyager, and Spacelab 1 experiments are described in greater detail along with other active projects of the Center in the following sections of this report.

Total research operations in the Center for Space Research for 1976-77 were about \$3,600,000 and engaged some 20 faculty, 60 research staff and support personnel, and nearly 100 students. Primary support for the Center's program came from NASA; additional support came from the National Science Foundation, US Air Force, and US Navy.

Some high points of the research in a much condensed form follow below. More technical detail for certain of the research efforts may be found in appropriate departmental sections of this annual report, and in Space Center research project reports and publications.

The plasma experiment payloads for the Mariner Jupiter/Saturn 1977 Mission (recently renamed Voyager) have been completed and delivered to the Jet Propulsion Laboratory. Launches of the twin spacecraft are scheduled from Kennedy Space Flight Center in August 1977 aboard separate Titan III E/Centaur D-1T launch vehicles. Flyby of Jupiter will occur in early 1979 and flyby of Saturn in early 1981. The plasma experiments under the direction of Professor Herbert S. Bridge, Department of Physics, are among 11 separate science investigations to be conducted from the Voyager spacecraft. The plasma experiment is designed to investigate the flux of ionized particles emanating from the Sun while in the interplanetary region, to study the morphology and composition of the Jovian and Saturnian magnetospheres, and to measure the plasma interactions with the inner satellites, their possible atmospheres, and the rings of Saturn. After leaving Saturn the Voyager spacecraft may experience a future encounter with Uranus as they journey to the outer reaches of the planetary system.

The two Solrad II satellites launched into Earth orbit in spring, 1976 carried solar wind experiments conceived and designed by M. I. T. students under the supervision of Dr. Alan Lazarus, Senior Research Scientist in the Department of Physics and the principal investigator. Observations are continuing. An interesting check on simultaneous reporting of plasma properties by two independent satellites is being looked forward to as the Solrad II satellites come into proximity with the IMP H and J satellites. The latter satellites were launched in 1972 and 1973 respectively with M. I. T. plasma payloads and are still producing useful data.

The M. I. T. X-ray observatory on the Third Small Astronomy Satellite, SAS-3, continued to function well during the past year. On May 7 it began its third year in orbit. The observatory is controlled from the Goddard Space Flight Center in accordance with directions sent from the operations room in the Center for Space Research at M. I. T. The data are sent via a reserved data line to M. I. T. within a few minutes after they are received by the NASA tracking station at Quito, Ecuador. This rapid response makes it possible for X-ray astronomers at the Center for Space Research to use the observatory in a highly interactive way and to adjust observing tactics on short notice in response to unexpected developments and discoveries. Among the most interesting results from the SAS-3 observations during the past year are the discovery of more than a dozen sources of repetitive X-ray bursts, the discovery of powerful X-ray emission from the Seyfert galaxy 3C120, and the determination of the dynamical properties of pulsating binary X-ray sources through the measurement of the Doppler variations of their pulse frequencies. The latter investigations have led to significant refinements in the determination of the masses of the neutron stars which are the actual sources of the X-rays in these binary systems.

The High Energy Astronomical Observatory (HEAO-A) was scheduled for launch in April 1977. However, malfunction of the spacecraft gyroscope stabilization system during pre-launch checkout has delayed the launch until July 1977 at the earliest. Professors Bradt and Lewin are each co-principal investigators on two separate X-ray experiments on this first of a series of large Earth-orbiting science satellites. The HEAO-A instruments have much greater

sensitive areas than those of previous satellites. Hence many fainter sources should be detectable and more precise measurements of known sources should result from the HEAO observations.

The construction of the focal-plane Bragg crystal spectrometer payload for the High Energy Astronomy Observatory, HEAO-B, has been completed. This experiment will be one of several to be used at the focal plane of the 0.6 meter X-ray telescope to be flown in 1978. The project is under the direction of Professor Clark assisted by Professor Canizares.

Preparations are in an advanced stage for a resumption of balloon-borne X-ray experiments from the Northern and Southern hemispheres. This research is under the supervision of Professor Lewin in cooperation with the Cosmic Ray Working Group at Leiden University, Leiden, The Netherlands. Observations are scheduled to take place from Palestine, Texas, in May 1978, and Australia in April 1979. High energy X-ray observations of galactic and extragalactic objects ($\approx 18-150$ KeV) will be conducted using detectors of unprecedented sensitivity. It is expected that burst or flare-like changes in source intensities on characteristic time scales 4 to 5 times shorter than previously possible, will be observable.

Design and construction of new instruments for detecting low-energy X rays from sounding rockets have proceeded during the year with a current launch objective from White Sands, New Mexico, in July 1977 aboard an Astrobee rocket. The proportional counter for this new flight was provided by an X-ray research group at the University of Leicester, England. The M. I. T. research is under the direction of Professor Rappaport.

Optical observations of binary X-ray stars, detected in the X-ray band by SAS-3, have continued at the McGraw Hill Observatory at Kitt Peak, Arizona, and the Cerro Tololo Interamerican Observatory. The McGraw Hill telescope is operated cooperatively by the University of Michigan, Dartmouth, and M. I. T. under a long-term agreement making the telescope available to student observers as well as professional observers. Dr. Jeffrey McClintock of the Center for Space Research is in charge of the M. I. T. program.

Professor Susan G. Kleinmann of the Department of Physics and her student assistants have concentrated most of their efforts on studying the results of the first mid-infrared sky survey, carried out by the US Air Force and published in 1975. For the sources that could be confirmed, a number of diagnostic observing programs were carried out utilizing optical, infrared, and microwave spectroscopy and far-infrared photometry to determine their relationship to other known infrared sources.

Near-infrared observations of selected optically identified X-ray sources were also conducted which, besides yielding direct estimates of the amount by which the sources are obscured by interstellar matter, produced important physical properties of the infrared sources and their optical/X-ray radio counterparts.

High-resolution ($\lambda/\Delta\lambda \sim 10^5$) near-infrared observations of selected variable stars and obscured objects were initiated. The goals of these studies are, respectively, an understanding of the kinematics of the atmospheres of cool stars and abundance determinations in dark clouds, including, especially, the detection of H_2 in regions where it is the dominant constituent.

The National Aeronautics and Space Administration has accepted a proposal by Professor Young to perform a series of vestibular experiments in Spacelab 1 in the 1980-81 time frame. The Center's Laboratory for Space Experiments, headed by Dr. Joseph H. Binsack, will provide management and engineering support. Several Canadian co-investigators from the Defense and Civil Institute for Environmental Medicine will cooperate in this opportunity to test theories in the gravity-free environment of Spacelab. Seven separate experiments are planned, some in collaboration with European Space Agency investigators. The experiments

will range from the measurement of various responses to sled accelerations, to hopping experiments which will test otolith changes during weightlessness and memory/disorientation experiments focusing on previous problems experienced by astronauts in the Skylab mission. Professor Young will be assisted in the Spacelab experiments by Professor Charles M. Oman of the Department of Aeronautics and Astronautics.

Other areas of investigation by the staff of the Man-Vehicle Laboratory under Professor Young's direction include research on the integration of visual and motion cues for flight simulation, habitation to novel visual vestibular environments, design of a test chair for clinical vestibular testing; compensatory visual neural changes with eye movements by Dr. Howard T. Hermann and studies in strategic arithmetic by Dr. Alan Natapoff, both of the Department of Aeronautics and Astronautics.

The research of the Laboratory of Neuroendocrine Regulation under the direction of Professor Richard J. Wurtman, Department of Nutrition and Food Science, has continued to examine the effects of environmental inputs such as light and food on the physiology of vertebrates. Experiments in space, perhaps as early as Spacelab 2, constitute one of the primary objectives of this research.

Institute Professor Philip Morrison and Professor Kenneth Brecher, both of the Department of Physics, have continued their theoretical investigations in astrophysics and cosmology under NSF sponsorship. This work included the analysis of observations of supernovae and novae; studies of neutron stars, white dwarfs, and pulsars; and studies of the nature of quasars, galactic nuclei, and radio galaxies. Continuation of the research for an additional three years has been proposed including studies of the fast (burst) variable, galactic X-ray sources from the SAS-3 observations.

Research on the use of composite materials in space structures of interest to the US Air Force was continued during the past year and is to be extended under a new contract beginning in June 1977. The work to date has narrowed the field of candidate design concepts to the point where dynamic response to applied loads during launch may be usefully investigated. Studies of the reaction of representative specimens to cold soak at cryogenic temperatures simulating long periods in Earth shadow is planned under the new program. Coordination with industrial firms contemplating actual space applications is being done. This research is under the general supervision of the Director of the Center, with Dr. Oscar Orringer of the Department of Aeronautics and Astronautics assisting.

Negotiations are continuing with the aim of broadening the base of scientific and technical space research investigations having mutual interests to the Center and other potential M. I. T. principal investigators. This aspect of the Center's program will be particularly important as the age of the operating Space Shuttle comes to fruition.

JOHN F. MCCARTHY, JR.

Detroit Institute of Technology-M.I.T. Association

Evolving from meetings in 1970 between personnel of the Detroit Institute of Technology (D. I. T.) and M. I. T., the D. I. T. -M. I. T. Association was established in 1971 "to improve and strengthen the academic program of D. I. T." The activities of the Association are funded by the Detroit Institute of Technology which receives partial support for M. I. T.'s involvement

under a US Department of Health, Education, and Welfare grant for strengthening developing institutions.

During the past year, 10 M.I.T. faculty, staff, and outside consultants have assisted D.I.T. faculty and administrators in improving D.I.T.'s academic program. These personnel spent an average of 12 person-days per month working with their counterparts in Detroit. In addition to those involved on a continuing basis, a number of other personnel, including academic deans, administrators, and faculty, have contributed to M.I.T.'s efforts on a more limited basis.

M.I.T.'s original involvement in developing the New Study Program at D.I.T. has expanded and broadened into other areas at the school. The development of the Learning Center at D.I.T. was a joint effort by both institutions to serve the D.I.T. students who are lacking in the basic skills of mathematics and English. A major effort by both institutions has been toward the development of interdisciplinary courses in both the natural sciences and the social sciences. D.I.T. personnel and consultants are involved in the areas of biology, chemistry, physics, mathematics, engineering, computer science, urban studies, and English. Although the level and degree of interaction varies among these disciplines, the overall impact of M.I.T.'s activities at D.I.T. has been significant. There is a growing realization among D.I.T. faculty and administrators of the importance of commitment and need to the community in which D.I.T. finds itself. The relationship between the D.I.T. community and the Detroit community at large is becoming a major educational focus.

In addition to efforts in the academic area, M.I.T. has assisted D.I.T. in administrative areas. In June 1977, M.I.T. was host to D.I.T.'s newly appointed President, Dr. Hugh Thompson. Dr. Thompson was met by the Vice President for Research, the D.I.T.-M.I.T. Coordinator, M.I.T. staff, and Association members. M.I.T. continues to assist D.I.T. in developing and implementing programs which are based on the needs of the student population and the assessment of data related to present and future employment opportunities.

HOWARD A. MARKOWITZ

Energy Laboratory

During the past year, Energy Laboratory funding and personnel have continued to increase. Laboratory projects now involve 60 Energy Laboratory staff, 70 faculty, and 150 students from various departments in all five M.I.T. Schools. The annual budget for the Laboratory is over \$7 million, of which \$450,000 are discretionary funds used to develop projects in new research areas.

The administrative structure of the Laboratory has been revised to better reflect and support the research under way. The current program areas are shown below with descriptions of selected projects which are representative of each. Professor Jean F. Louis and David O. Wood were appointed associate directors of the Laboratory, and they and the director each take responsibility for specific program areas. In addition, each area has a program director and most have program managers.

The Institutional Agreement between the US Energy Research and Development Administration (ERDA) and M.I.T. continued into its second year, under Energy Laboratory management. Twenty-seven task orders are under way, 16 of which are based in the Energy Laboratory.

Funds allotted directly to the Energy Laboratory were used for educational activities, exploratory research, and program coordination. Two new M. I. T. subjects were developed using these funds and were offered during the past academic year. Twenty-two exploratory projects were supported, several of which have led to the funding of new task orders. Efforts at information transfer resulted in a number of successful conferences and the expansion of information services in headquarters.

In order to increase the nation's capability to make effective energy policy, the Energy Laboratory formed an M. I. T. Center for Energy Policy Research during the past year. This Center establishes a collective effort by industry, labor, public interest groups, government, and other universities on long-run energy policy issues. The main objectives of the Center are: to build a resource base of technically competent, comprehensive studies of important issues of government, corporate, environmental, and labor policy in the energy area; to use this analysis to support the preparation of papers on individual policy issues directed towards operating executives, government officials, and the informed public; and to support these policy studies with an improved foundation of data and research results on fundamental areas of energy economics, technology, and management.

The Center is organized within the Energy Laboratory with separate funding authority, a Center operating committee, and an advisory board made up of representatives from sponsoring organizations. Invitations to participate have been extended to an initial group of organizations, with the understanding that a commitment to intense professional interaction and collaboration is vital. Emphasis will be given to establishing diversity in participants and sponsors in order to maintain the objectivity and credibility of the Center. To encourage sponsor participation in Center projects, a program of Center Fellows is being organized.

A major program was undertaken to upgrade and extend experimental facilities to support work in fossil fuel utilization technology and health effects. As a result, a magnetohydrodynamics simulation facility has been built and is being used by both M. I. T. and industry. A major combustion facility is under construction, including a fluidized bed combustor. Also proposed are facilities for investigating electrofluidized beds, fluidized bed pyrolysis, and combined cycles; an emissions toxicology laboratory; and supporting instrumentation, computation, and data acquisition capabilities.

In the past year a contract was signed establishing a series of energy documents to be published by the M. I. T. Press in conjunction with the Energy Laboratory. An editorial board of Laboratory personnel was created to encourage and review manuscripts from M. I. T. researchers. In addition, the M. I. T. Press editorial board gave overall approval to a series of energy policy monographs, alleviating the need for outside reviews of individual manuscripts. Several policy monographs are currently being edited and reviewed by the Laboratory editorial board.

The Electric Power Program continued to serve the research and development needs of electric utility companies located in the northeastern United States. During the past year funding from New England Electric and Northeast Utilities supported projects in the environmental and nuclear areas. However, discussions with the R&D directors of these and other potential utility sponsors led to a decision earlier this year to replace the Electric Power Program with a new program. The new program was initiated in January and is called the Electric Utility Research Seminar and Workshop Program. It is organized around a continuing series of seminars and workshops designed to: 1) inform utilities about ongoing research projects, interests, and capabilities at M. I. T. ; 2) identify and discuss utility research needs and priorities; and 3) develop multisponsored or individually sponsored research projects. The seminars and workshops are being jointly sponsored by M. I. T. and the participating utilities. Research projects developed from the workshops will be sponsored by one or more of the participating utilities -- according to their needs and interests. A number of proposed

projects are presently under consideration for funding during the coming year. Utilities currently participating in the program are Boston Edison, Eastern Utilities Associates, Fitchburg Gas and Electric, New England Electric, Northeast Utilities, and Public Service of New Jersey. The program is under the direction of Dr. William Hinkle.

During the past year the Energy Laboratory Reading Room grew by about 200 volumes to a total exceeding 1,500 documents; journal subscriptions increased by about 30 percent. A new classification scheme has been devised and currently is being implemented. A full-time librarian has replaced part-time staff, making reference services available to Energy Laboratory staff, and to others as time permits. The Reading Room now provides acquisitions and reference services that are vital to current research in the Laboratory.

The following summaries describe some of the Energy Laboratory projects which were active during the past year.

MANAGEMENT AND ECONOMICS

Mr. Wood and his colleagues have recently undertaken a large program of economic research and modeling in support of ERDA's Photovoltaic Energy Conversion Program. The program involves projects in the following three areas: economic analysis and support of photovoltaic tests and applications; research and modeling of photovoltaic technology demand and supply; and studies of environmental, institutional, and regulatory issues relating to this technology.

Professors M. A. Adelman, Henry Jacoby, and Robert Pindyck are developing methods of analysis and supporting data for studying the behavior of the world oil market, in particular, the oil cartel. Econometric studies of world demand for petroleum products and analyses of oil supplies from noncartel sources are being combined in a market simulation model that will aid analysis of the cartel as it attempts to manipulate price and quantities of this critical commodity.

Professors Adelman, Martin Zimmerman, and Gordon Kaufman have undertaken a review and assessment of the methodology of resource and reserve estimation for coal, oil and gas, and uranium. A nontechnical description of the resource and reserve estimation process will be developed and uncertainties demonstrated in hopes of identifying areas where the most significant payoffs in improved data and information would occur. The assessment will present, analyze, and compare existing resource and reserve estimates and will provide a comparative evaluation of the basis and data upon which these estimates were made.

Professor Zimmerman has estimated supply functions for coal in the United States using geological information about the mineral remaining in the ground. The supply functions are estimated separately for each major coal-producing region and are disaggregated by type of mining and by sulfur content. The regions are linked to consuming areas through transport rate equations reflecting costs as well as market power.

Professors Kaufman and Eytan Barouch have made significant progress on a mathematical model of the oil and gas discovery process. The probabilistic model is being built from assumptions about specific geological, technological, and economic attributes of the process of exploration technology and observed statistical regularities of the size of petroleum pools which interact to influence discoveries.

Professor Pindyck has updated, revised, and expanded his 1,200-equation computer model of US natural gas production and wholesale consumption on a disaggregated level. This

model is being used to simulate the effects of various Federal and state regulatory policies on the size of the US gas shortage from 1976 to 1980, and to analyze regional effects and the demands for substitute fuels.

Professor Edwin Kuh and Mr. Wood have organized a joint Energy Laboratory-National Bureau of Economic Research project to undertake assessments and evaluation of selected energy system models. The project, supported by the Electric Power Research Institute, is currently involved in an assessment of the M. I. T. Regional Electricity Model.

Professor John Donovan and his colleagues have continued M. I. T. 's regional energy work, including work on the New England Energy Management Information System (NEEMIS). This effort has provided a body of energy related data for regional analysis; application programs and models for analysis and policy studies as they affect regions; and a group of energy specialists working on regional problems who are accessible to energy policy officers.

Drs. Robert Baron and Ogden Hammond and Mr. Wood recently completed a study of residential fuel oil demand in Massachusetts. This study provided an explicit description of the demand by consumers for energy conserving investments as a function of fuel prices, conservation costs, and the rate of return required by consumers.

Dr. Esteban Hnyilicza has begun investigating the potential contribution of modern systems theory in the development of methodologies for evaluating trends in the availability of primary energy resources. Critical reviews of the theoretical and empirical literature are being completed, and an empirically based prototype model is being developed for the optimal rate of exploratory drilling for petroleum.

Dr. Ernst Berndt, a visiting scholar from the University of British Columbia, and Mr. Wood continued their research on the demand for energy and other factors of production in US manufacturing. Recent contributions include an analysis of investment incentives for energy conservation in US manufacturing and an international survey of econometric studies of energy and other factor demands.

Dr. Hnyilicza and Mr. Wood participated in a study sponsored by the Electric Power Research Institute Energy Modeling Forum to analyze the contribution of current energy system models in explaining the relation between energy markets and aggregate economic growth. The macroeconomic energy model developed by Dr. Hnyilicza was one of the models considered in the study.

Professor Donovan and his colleagues also continued work on the IBM Joint Study Agreement. This agreement has provided support for the development and use of an advanced computational facility called Generalized Management Information System (GMIS). GMIS is being used by most of the projects in the Management and Economics program area of the Laboratory for portions of their modeling and data analysis efforts.

POLICY STUDIES AND TECHNOLOGY EVALUATION

Dr. Lawrence Linden and Professor Jacoby, leading an effort by the Policy Study Group, completed their study of issues associated with government programs designed to accelerate the "commercialization" of emerging energy production, conversion, and end use technologies. They concluded that a national energy R, D&D program should reduce the costs of existing and emerging substitutes for oil and gas, both of primary energy types and of other factors of production. Also, ERDA should subsidize new technologies only to the extent that they are being impeded either by artificially low prices or by high regulatory uncertainties.

Professor J. D. Nyhart and Dr. Linden extended the above work by examining the impact of regulatory policies on the commercialization of oil shale. A review has been undertaken of the resources and technologies involved. The legal and regulatory issues are identified and explored in detail with an emphasis on developing concepts for resolution of problems.

Visiting Professor Mason Willrich completed his analysis of alternative institutional arrangements for the management and regulation of radioactive waste under US control. He concluded that the existing US management and regulatory arrangements for radioactive waste will be inadequate if they remain unchanged. He recommends the establishment of a national Radioactive Waste Authority and development of a comprehensive scheme of licensing all commercial and military radioactive waste in the US.

Professor David Rose, Mr. Wood, and a number of associates in the Departments of Nuclear Engineering and Economics and the Energy Laboratory have initiated a project to provide analysis and evaluation of technical and nontechnical strategies to improve the design, construction, and utilization of light water reactors (LWR). Issues under consideration include the industry/government incentives, obstacles, and constraints relating to each strategy.

Dr. Linden and Professor John Heywood continued their study of the Federal government's role in supporting the development of alternative automotive power plants. Work is progressing in three areas: the impact of the fleetwide fuel economy standards on industry funded research and development; issues in research strategy for the government; and a case study of the gas turbine engine.

The above research has led to a detailed study of the problems of the current national safety, fuel economy, and air pollutant emissions regulations. Professors Heywood and Jacoby are examining the underlying structural elements of the automotive regulatory system, the difficulties which result, and the reasons for society's choice of this mode of government-industry interaction in the automotive case.

Professors Pindyck and Robert Hall have investigated the inherent conflict between artificially low energy prices and the objective of self-sufficiency -- a conflict which must be resolved by emerging national energy policy. Their recommendations include removal of price controls on oil and natural gas, energy subsidies for lower income families, government support of basic research on promising energy technologies, and stand-by programs to deal with national security issues. They are preparing an analysis of the President's energy program within this framework.

END USE TECHNOLOGY

Professor Ernest Cravalho is developing a computer model based on the Brookhaven National Laboratory Reference Energy System that will define energy consumption patterns at the local level. Fairly accurate models at the county level have been developed. When completed, the models will be used to establish energy conservation strategies at the local level.

Professor Nicholas Negroponte and Guy Weinzapfel have developed a simple energy estimation routine which interfaces with an existing computer aided building design system. This design/estimation package allows the architect to make energy-efficient decisions during the early phases of design, particularly regarding building placement, massing, and orientation.

Professors Merton Flemings and Joel Clark organized a conference held at M. I. T. on May 25-27, 1977, entitled "Energy Conservation in Production and Utilization of Magnesium in the US." Industry, university, and government personnel exchanged research results in this area and discussed future R&D needs. Professors Flemings and Clark are also completing a systems study in conjunction with the conference concerning the effects that the substitution of magnesium for aluminum would have on energy use in the US.

Dr. Leon Glicksman and Professor Warren Rohsenow have continued investigating the cooling of underground high voltage electrical transmission lines. They have obtained an accurate prediction of the pressure drop in both the laminar and turbulent flow regimes. The central mechanism for heat transfer from the cables has been identified. In addition, a technique for predicting the three-dimensional transient conduction from the cable to the soil has been developed. The heat transfer and pressure drop results have illustrated the significant errors of the approximate design calculations in the literature. The resulting thermal-hydraulic design guidelines allow the determination of oil temperature level and pumping requirements for a given current level. A design manual and computer design program have been developed for utility use.

Dr. James Meyer and William Jones have completed their survey of opportunities to conserve energy at the St. Mark's School in Southborough, Massachusetts. A methodology was developed for preparing energy audits and energy flow charts and for evaluating energy requirements for specific purposes. Solar energy applications were considered, and a supplemental solar hot water system was found to have the greatest potential for significant return on investment.

ADVANCED TECHNOLOGY

A new area of emphasis in the Energy Laboratory is research directed toward development of basic engineering data and of advanced technologies. Much of this work is directed toward the development of new materials and new materials processing techniques for energy conservation and storage, and for advanced energy conversion systems. For example, an electrode and electrolyte fabrication facility has been established in conjunction with the new Ceramics Processing Research Laboratory. New interdisciplinary programs have been organized by Professor H. Kent Bowen and Dr. John Haggerty for research on laser driven chemical reactions, solar energy materials, fuel cells and catalysis.

James Kafalas is leading an effort to develop a solid electrolyte other than β -alumina for use in sodium-sulfur batteries. Because of their high energy and power densities, such batteries would be very suitable for electrical vehicle propulsion and utility load-leveling applications. A promising new solid electrolyte has been discovered and is being used in developing practical ceramic membranes for battery use.

Professor Mildred Dresselhaus and her group progressed with their study of the rate of certain chemical reactions at the surfaces of magnetic metals, particularly as affected by magnetic fields. In this connection, a system has been constructed to accurately monitor the formation rate of nickel carbonyl. Magnetic field enhancement of this formation rate as reported by certain Russian workers could be of commercial significance because this reaction is an intermediate step in the commercial nickel purification process.

Because of its strength, corrosion and erosion resistance, and high temperature stability, the possibility of using silicon carbide to make highly efficient heat engines is of interest. Professor Rowland Cannon, Jr. is determining methods of controlling grain size and grain morphology in silicon carbide while maintaining control over other important variables including density, matrix phase, second phase characteristics, and grain boundary chemistry.

Professor Rene Miller continued his work on the development of wind turbine design technology with specific reference to aerodynamics, dynamic stability, and the prediction of fatigue loads. Initial experimental efforts verified the importance of dynamic and aeroelastic phenomena in large wind turbine design. Current work considers the dynamic coupling between the rotor, the drive system, and the tower, including nonlinear stability analyses as necessary.

ENERGY CONVERSION

A long-term, interdepartmental study of magnetohydrodynamics (MHD) power generation continued under the direction of Professor Louis. This effort is part of a national ERDA program to develop open-cycle, coal-fired MHD as a source of electrical power.

The goals of the MHD group are centered on the first elements of the development program needed for MHD power plants. These elements are: a) engineering analysis; b) scientific demonstration of new concepts at the laboratory bench scale; and c) engineering demonstration of successful scientific concepts at the minimum critical scale. With these goals in mind, activities are focused on the critical areas of interelectrode breakdown, disk generator performance, generator stability, maintenance of electrodes and insulators in the presence of clean gases and slag, development of new electrode materials, coal devolatilization, ash behavior, slag condensation, description of plasma properties, generators and MHD systems.

Since fluidized bed combustion (FBC) systems will soon undergo commercial application, a model capable of predicting FBC performance is needed to optimize the process and/or engineering design of plants under various sets of conditions. Professor Louis, Dr. Shao Tung, and their colleagues have developed a general structure diagram of an FBC model which includes five component models, namely, a fluid dynamics model, a desulfurization model, a heat transfer model, a combustion model, and a materials model. Nine data base systems have been evaluated; a prototype data base system has been set up; input procedure has been written; and some data from the literature has been entered into this prototype data base. A final data base system will be selected in the near future.

The combined cycle research program, directed by Professor Louis, is aimed at providing essential data for the development of combined gas turbine-steam turbine power plants with overall efficiency and operating cost advantages over conventional steam power plants. This three-year effort will concentrate on critical areas related to gas turbine performance and reliability: turbine cooling with air and liquids, turbine materials corrosion in an industrial environment, and high temperature fuel gas desulfurization. The first year has been spent building and modifying research facilities, reviewing available literature, developing analytical models, and conducting preliminary tests.

Professor James Melcher continued his investigation of the electrofluidized bed (EFB). Successful laboratory tests have been made and a prototype EFB unit is scheduled to be tested, with flue gases from the MHD processing system being passed through a newly developed EFB filter. Based on the success of this study, a program to design, build, install, and test a full-scale EFB unit has been proposed and the feasibility of this approach evaluated.

Dr. J. Derek Teare and his colleagues continued their assessment of the potential environmental impact of various advanced energy conversion technologies in order to avoid the need for retrofitting control equipment when these plants are a commercial reality. Preliminary studies consolidated information available on the potential pollutants and on the current state of development of the advanced technologies. Realistic and practical analytical models have been developed to estimate effluents, pollutants, and waste energy.

COMBUSTION

The School of Engineering and the Energy Laboratory have embarked on a broadly based research program on the combustion of fossil fuels (oil, gas, and coal) and new, coal derived fuels such as low-Btu gas, solvent refined coal, coal in oil mixtures, and oil-water emulsions. Central to this program is the design, construction, and operation of two pilot-plant sized experimental facilities: a versatile experimental furnace with variable heat sink and multifuel burning capability, and a fluidized bed combustor. M.I.T. has committed considerable funds to the design and construction of these experimental facilities which, when completed in 1978, will play an essential role in studies on the clean combustion of coal and coal derived synthetic fuels, and on the scale-up of results of basic combustion research to their application to industrial processes.

Professors Janos Beér and Adel Sarofim have proposed a combustion research program for clean combustion of coal derived fuels and prepared a conceptual design of a versatile experimental furnace with heat input up to 3 MW, multifuel burning capability, and variable temperature heat sink. A design team consisting of Professor Beér, Dr. James Nash-Webber, Walter Farrell, and Rolf Steendal has completed the detailed design of this combustion research facility (CRF) which is presently under construction and is expected to be available for research early in 1978. An Industrial Advisory Committee was formed to assist in the planning of the research program for the CRF and the application of the results in industrial design and research and development. The Committee has members from the manufacturing industry, the fuel industries, users of combustion equipment, and government agencies concerned with energy utilization.

Professors Beér and Sarofim have prepared a preproposal to ERDA on the study of coal in oil mixture combustion using the CRF. It is proposed to determine the combustion and slagging characteristics of coal in oil slurries as a function of the coal/oil mixture ratio, coal particle size, slurry atomization quality, and the flow and mixing pattern in the flame.

Professor Beér has developed a method using a novel multiannular swirl burner design, which achieves clean and stable combustion of gas and heavy fuel oils by the suitable overlapping of high fuel concentration regions of flames with regions of high turbulence in the flow. Professor Beér and Dr. Ashwani Gupta are investigating the application of this principle to furnace and gas turbine combustor design. A research application is being prepared for submission to ERDA on the study of combustion of low Btu gas and heavy fuel oil using the multiannular swirl burner design.

Professor Beér is investigating the formation and destruction of NO in fluidized bed combustors. A number of graduate students supervised by Professors Sarofim and Beér are carrying out experimental studies on the reactions which lead to the reduction of nitric oxide by coal volatiles (fuel-N compounds) and by char in the fluidized bed.

Professor Beér, Dr. Nash-Webber, and Gerrard Power have completed design of a pilot-plant sized fluidized bed combustor (2 feet by 2 feet cross section, 15 feet high) which will enable the experimental investigation of fluidized combustion processes by detailed gas and solid particle sampling from points in the fluidized bed and the "freeboard" above the bed. The pilot plant experimental fluidized combustor is under construction and is expected to be available for research in fall, 1977.

Professor Heywood and Dr. Rodney Tabaczynski have completed development of their spark-ignition combustion model which incorporates the effects of turbulence and fuel composition in assessing lean burning engine concepts and components. This model allows the performance of realistic parameter studies for engine optimization.

Most of the unburnt hydrocarbons in the combustion chamber of a gasoline engine occur in a thin layer of gas adjacent to the walls. Professors Heywood and James Keck are leading a study of various aspects of this "quench layer." The exhaust phase of an experimental engine is being examined, in particular the mixing and combustion occurring in the exhaust system and the motion of the piston sweeping up the quench layer prior to exhaust.

Professor Heywood has completed his study of the potential of methanol as a future automotive fuel. His research team examined some of the fundamental aspects of spark-ignition engine operation with methanol alone, with methanol-water mixtures, and with methanol-gasoline blends, and the phase stability characteristics of these blends.

Professors Heywood and Sarofim are concluding an investigation into a method for reducing the emissions of nitrogen oxides from stationary sources burning nitrogen-containing fuels. The proposed control technique is based on the use of high air preheat to obtain flame temperatures high enough to overcome the kinetic limitations which normally result in the emission of a combination of bound nitrogen intermediates and nitrogen oxides. A burner has been built which will permit the combustion of nitrogen-containing distillate oils in a controlled manner with varying amounts of air preheat.

FUEL CONVERSION AND HEALTH EFFECTS

A research team headed by Professor Lawrence Evans has made substantial progress towards developing a third generation computing system for chemical process engineering. The software system will play an important role in the 1980s in developing new fossil energy processes. For a system such as a coal gasification plant, it will perform the steady-state material and energy balances, size the equipment, and carry out an economic evaluation. During the past year a prototype computer system was designed and used to explore the basic system structures necessary to accommodate the range of processes encountered in energy conversion and conservation.

Professors Jack Howard and John Longwell and Dr. William Peters are leading a research program to determine the technical feasibility of producing low sulfur, high heating value fuels suitable for generating peak load power in gas turbine equipment by pyrolyzing coal in the presence of hot, sulfur-accepting stones. The operating characteristics of a cold model fluidized bed of coal have been studied, and a hot reactor outfitted for continuous solids feeding and product recovery is now being tested.

Professor Howard and Dr. Peters are continuing their fundamental studies of the pyrolysis and hydrolysis of coal under conditions pertinent to practical scale conversion processes. Rates and extents of production of volatile products, as well as sulfur and nitrogen contents of chars formed by pyrolysis and hydrolysis of coal and lignite have been determined. Emphasis is on development of generalized correlations and models of coal pyrolysis and hydrogasification.

Many gasification and pyrolysis processes produce large amounts of char which must be utilized to make process economics favorable. Using modified M.I.T. equipment, Professors Howard and Sarofim have been producing basic data on rates and extents of char gasification pertinent to the Bigas pilot-plant program managed by the Phillips Petroleum Company.

A long-term, multidisciplinary effort has recently been initiated to investigate the relative health hazards of employing lower quality fossil fuels such as coal and coal- and shale-derived liquids as major energy sources. Building on well-established research strengths in combus-

tion under Professor Howard, in analytical chemistry under Professor Ronald Hites, and in genetic toxicology under Professor William Thilly, the program will focus on relating the toxicities of soots and polycyclic aromatic hydrocarbons from combustion systems to fuel composition and burner operating conditions. Emphasis is given to qualitative and quantitative identification of polycyclic compounds and to utilization of biological assays that reflect as closely as possible the responses to be expected in human tissues.

NUCLEAR TECHNOLOGY

Professor Michael Driscoll has continued his work to determine the capability of reducing the uranium ore and separative work requirements of current light water reactor designs, primarily through utilization of thorium, but including other options such as lattice redesign and fuel interchange between light water reactors and breeder reactors. A simple analytical model has been formulated which can predict the ore and separative work requirements of various reactor systems.

Professors Neil Todreas and Lothar Wolf have developed methods for thermal hydraulic analysis of light water reactors for utility use. A simplified procedure using existing codes to predict pressurized water reactor behavior was developed and is being confirmed. In addition, a subchannel code especially suited for building water reactors is being extended and extensively tested.

Professor John Meyer has continued research into methods to calculate the performance of nuclear fuel rods used in light water reactors. An approach has been developed to improve the basis for utility decisions on placement of new and retained fuel assemblies during refueling. Ongoing work includes a study of allowable reactor up-power ramp rates and an evaluation of computer codes by comparison to experiments.

Professor David Lanning has made significant progress on improving the M. I. T. computer-code library. Fifteen new codes have been acquired, providing the following improvements: up-to-date basic neutron cross-section information and evaluated cross-section sets; capability for nuclear fuel management and design calculations; thermal hydraulic calculational methods; reliability and fault-tree analysis codes for reactor safety studies. Additional computing capability and a remote access system have been added for enhancement of the computer utilization and capabilities.

Professor Otto Harling has moved into the experimental stages of his effort to simulate, using a research fission reactor, the degradation of the mechanical properties of candidate fusion reactor first wall materials caused by the synergistic interaction of helium gas and radiation induced defects. A feasibility study is under way involving 316 stainless steel and a rapid strain rate to failure tensile test.

Professor Harling has also developed a detailed program for research to reduce costs related to radiation exposure during the maintenance of light water reactor primary coolant systems. This program will involve designing and building an in-reactor recirculating loop that simulates both the thermal-hydraulic and radiation environment of a commercial pressurized water reactor.

ENVIRONMENTAL MANAGEMENT

Professors Donald Harleman, Keith Stolzenbach, and Dr. Gerhard Jirka have continued their efforts to identify the trade-offs between environmental impacts and energy conservation in present and future waste-heat management technologies in electric power generation from fossil or nuclear fuels. They are assessing the short- and long-term energy resource consumption and environmental impacts associated with various types of cooling systems, and are developing operational strategies for cooling systems to meet environmental constraints while maximizing electric power output.

Dr. Jirka has continued his study of the external fluid mechanics of ocean thermal energy conversion (OTEC) plants. A laboratory model of a schematic OTEC plant has been constructed to simulate the upper layer of the stratified ocean. Mathematical zone models for the initial jet mixing region have been developed and are being compared with experimental data.

Dr. Leon Glicksman has received encouraging experimental results on his unique design for a wet/dry cooling tower. Experimental measurements from a heat transfer test apparatus agree very closely with a predictive model which has been developed for the new design. Results show that the new design can reduce evaporation to between 20 and 50 percent of a conventional wet tower for the same total heat rejection rate.

Professor Jerome Connor, Jr. is continuing to examine different strategies for incorporating state estimation techniques into infinite element numerical models for predicting circulation and dispersion of effluents in water bodies. Results will be applicable to a wide range of environmental issues related to energy facilities located adjacent to a water body or in the offshore coastal zone. The trajectory of radioactive and other pollutant releases is of particular interest.

Professor Harleman and Dr. Jirka concluded an analytical and experimental study of submerged multiport diffusers for discharge of power plant cooling water in the coastal zone. A predictive model was developed which allows the computation of the temperature and velocity fields which are produced in the coastal environment.

Professors Sallie Chisolm and Stephen Moore have continued research aimed at improving the information obtained and the cost-effectiveness of ecological monitoring programs maintained and operated by utility companies for receiving waters subject to withdrawal and discharge of power plant cooling water. Alternative analyses of exposure panel data are being developed and carried out, and changes in the present exposure panel monitoring program will be proposed in order to reduce costs.

Professor Michael Golay concluded his experimental and analytical study of chemical drift from evaporative cooling towers and the carry-over of entrained liquid droplets (and their dissolved solids) in the tower's effluent stream. Three eliminators were investigated, and the agreement between predicted and experimentally observed behavior was generally good.

Dr. Glicksman constructed and is operating two facilities which test his innovative periodic cooling tower. An extensive modeling effort has been made to predict the performance of the rotor system as a function of the system geometry, the water and air conditions, and the oil layer. The design promises to be economically superior to the conventional dry tower. A large manufacturer and an architect/engineer are now working with the Energy Laboratory in a cooperative program to develop a prototype cooling tower design using the innovative concept and to determine the potential for cost savings.

Professor John Wilson has developed a numerical computer simulation for analyzing the influence of Western strip mines on regional groundwater flow and on the local flow through the mining site. The work has established the flowfields for several typical mining techniques and will be used for the development of guidelines for groundwater quality control.

ELECTRIC POWER SYSTEMS

Professor Fred Schweppe, Michael Ruane, and Dr. James Gruhl completed their project to test and extend existing technology for supplementary control systems (SCS) for SO₂. The demonstration project assessed existing air quality in the vicinity of the sources to be controlled; designed an SCS for these sources; implemented the design; and analyzed the results. The system design included realtime monitors, meteorological and air quality forecasting, and a probabilistic multiplant control strategy utilizing linear programming at the unit commitment time scale.

Dr. Gruhl and Professor Schweppe cooperated with Argonne National Laboratory in a project to compare alternative methods of coal fired generation of electric power. They designed a methodology for systems analysis of the technical, environmental, and economic data which Argonne collected on technologies for fuel treatment, combustion, and post-combustion treatment.

Mr. Ruane and Professor Schweppe also developed a Generation Expansion Model (GEM) which incorporates explicit environmental concerns into the electric utility planning process. Progress has been made towards creation of an operational model: major components have been created or revised, forming a complete model; components have been tested using a reduced test system; and work is under way to perform a system comparison test with planning data from a New England power company.

DAVID C. WHITE

Laboratory for Nuclear Science (L.N.S.)

The L.N.S. provides support for research by faculty members and associated research staff in the fields of nuclear and elementary particle physics. It supports the activities of the Center for Theoretical Physics in these fields, and provides a computing facility for the experimental and theoretical programs. Use of this facility is shared by some activities of the Center for Space Research and some other Institute programs. The Laboratory supports experimental programs in three areas: elementary particle physics, with programs at accelerator facilities in the United States and two in Europe; intermediate energy nuclear physics, centered at the Bates Linear Accelerator operated by L.N.S. in Middleton, Massachusetts; and heavy ion nuclear physics with major programs at two American accelerator facilities and lesser projects at several others.

Progress of the work at the Center for Theoretical Physics is reported elsewhere in this volume.

ELEMENTARY PARTICLE PHYSICS

Experiments in this field are increasingly marked by the large scale and technical complexity of the apparatus involved. This requires not only the formation of large research groups but, usually, collaboration of several institutions in addition to the accelerator laboratory where the experiment is performed. The three groups into which the efforts of L. N. S. have been consolidated are engaged in experiments at four facilities: Fermi National Accelerator Laboratory (FNAL) in Batavia, Illinois; Stanford Linear Accelerator (SLAC) in Stanford, California; European Center for Nuclear Research (CERN) in Geneva, Switzerland; and German Electron Synchrotron Laboratory (DESY) in Hamburg, Germany.

The Electromagnetic Interaction Group completed preparation for an experiment using the Intersecting Storage Ring at CERN and expects to obtain results in the near future. This experiment extends to higher energies their earlier effort at Brookhaven National Laboratory which resulted in the discovery of the J particle for which Professor Samuel C. C. Ting shared the 1976 Nobel Prize in Physics. At the same time this group is preparing equipment for a similar experiment using the electron-positron colliding beam facility, PETRA, now under construction at DESY. The host laboratories are generously providing large amounts of equipment and logistic support for these experiments. Nevertheless, the simultaneous involvement in two multimillion dollar projects overseas has proved a challenge to the financial and administrative resources of L. N. S.

The Accelerator Physics Collaboration Group is taking the lead of an international consortium of 12 US and 11 foreign institutions organized to exploit and improve the Hybrid Bubble Chamber facility at FNAL. This is a unique combination of electronic detection devices with a hydrogen bubble chamber, pioneered by this group. Among important results obtained during the last year was the observation of particle clusters in high energy collisions of pions with protons and the finding that a theoretical model developed by this group to analyze collisions between pions and protons at 4 GeV is also valid for glancing collisions at 150 GeV.

The Counter-Spark Chamber Group continued to exploit the magnetic spectrometer facility at FNAL which they helped to create. They are collecting a large amount of precise data concerning the energy and angular distributions of single secondary particles from high energy reactions. Many combinations of positively and negatively charged bombarding and secondary particles are studied. Such complete surveys have served as important tests of reaction theories at lower energies and it is hoped that the current experiments will serve this role for energies in the 100 GeV range.

Members of this group also participated in experiments at SLAC involving the interaction of high-energy electrons with protons and neutrons. These experiments have thrown further light on the quark-parton model of elementary particles.

INTERMEDIATE ENERGY PHYSICS

Operation of the Bates Linear Accelerator increased to more than 4,000 hours of beam time during the year as planned. Beam energy up to 350 MeV and currents in excess of 50 microampere were available when required for experiments. Currently active experimental programs involve 15 academic and research staff members and 12 graduate students, as well as collaborators from 15 institutions in the US and six foreign laboratories. In order to accommodate this expanding activity, ERDA has obtained Congressional approval of the expenditure of \$5 million for construction of a second experimental area which is expected

to be ready for operation during the second half of 1979. Considerable effort has been directed toward the design of major new equipment to be installed in this area. This has been aided by a week-long symposium in January sponsored by the Bates Users' Organization and by a Summer Study during June organized jointly with the Center for Theoretical Physics.

Inelastic electron scattering experiments continue to be the largest program, using about 60 percent of the available beam time. These experiments are designed to measure the distribution of electric charge and current, and of magnetization in nuclei with sufficient precision to permit detailed confrontation with theoretical models. This has involved increasingly refined calculations which exceed the present computational resources of L.N.S. We are exploring avenues to augment these resources.

Other successful experiments dealt with the ejection of protons and pions from nuclei by gamma rays.

HEAVY ION PHYSICS

The L.N.S. program in heavy ion nuclear physics is carried out primarily by experiments with accelerator facilities at Brookhaven National Laboratory and at the SuperHILAC facility at Lawrence Berkeley Laboratory. During the past year, effort was concentrated on three areas of research: important new evidence was obtained concerning "quasi molecular" states in which certain light nuclei seem to continue without coalescing immediately; experiments were carried out to study nonequilibrium processes which occur in collisions between nuclei before complete coalescence; and the study of fission in heavy nuclei was continued with a view to searching for super-heavy nuclei with measurable lifetimes.

Summary of Support

Participants in the various research programs during the past year amounted to approximately 480 persons. This includes 52 academic staff, 87 graduate students, and at least 120 undergraduates from M. I. T. and other institutions. The latter were involved in senior theses, UROP programs, work-study and similar programs. There were 58 research staff members with Ph. D. s including visitors and guests, and 164 employees in supporting categories such as engineers, technicians, machinists, computing and administrative personnel, etc. Over 40 active user physicists from other institutions participated in the program of the Bates Linear Accelerator. L.N.S. provided on-the-job training for 10 participants in the Cambridge-Arlington Comprehensive Employment Training Program. Eleven Ph. D. degrees, one S. M., and 15 S. B. degrees were awarded based on thesis research within L. N. S.

Support during fiscal year 1977 from the contract with the US Energy Research and Development Administration (ERDA) totaled \$8,900,000. This represents an increase of about 12 percent over the preceding year. This sum breaks down as follows: operations costs (salaries, wages, materials, services, travel, and overhead) \$7,505,000; of this \$3,005,000 for experimental and theoretical high energy physics; \$3,480,000 for intermediate nuclear energy physics for the support of the Bates Linac facility; and \$1,020,000 for nuclear structure theory and heavy ion experiments. Equipment costs \$975,000; of this \$325,000 for high energy physics and \$650,000 for medium energy and heavy ion physics. \$270,000 will be expended for accelerator improvement projects and \$150,000 for general plant projects

associated with the Bates Linear Accelerator. In addition, construction funds in the amount of \$5,000,000 were authorized and appropriated for expanded experimental facilities at Bates.

MARTIN DEUTSCH

Nuclear Reactor Laboratory (N.R.L.)

Fiscal year 1977 was the first year for the newly created Nuclear Reactor Laboratory. Sufficient progress in completing the several years of reactor modification permitted the return to full thermal power (5 MW) on December 1, 1976. Reactor usage has increased slowly during the year as previous users returned and as new projects were developed. Aside from completion of the reactor modification, the major emphasis of the laboratory management has been the development of new projects and organization development. Considerable progress has been made in reducing reactor operating costs and in increasing reactor income.

Neutron scattering activities increased in Professors Clifford G. Shull's and Sow-Hsin Chen's groups. However, the level of effort in these areas has not yet increased to the expected levels. The single crystal neutron interferometer experiment in Professor Shull's group is nearing operational usefulness and the new inelastic scattering spectrometer in Professor Chen's group has progressed to the point where full neutron tests are expected in the near future. Nuclear medicine research on boron capture neutron therapy for brain cancer, on special medical isotopes, and on nuclear tracer techniques continued, principally in Professor Gordon L. Brownell's group. Beagle dogs were used in a series of live animal studies designed to test the boron capture therapy procedures prior to tests on human subjects which it is hoped will begin in a year or two. Blanket neutronic research in support of the liquid metal fast breeder reactor program was continued under Professor Michael J. Driscoll's direction. Uses of reactor activation analysis studies in earth and planetary science were reinitiated by Professor Frederick A. Frey and his associates.

Several new projects were begun at the MITR-II during fiscal year 1977. Relatively large-scale production of a short lived medical isotope, ^{99}Mo , was initiated. This activity fulfills a need for a local New England area supplier of this important radiopharmaceutical. A new, modest sized project involving fusion reactor material irradiation testing has been started by Professor Otto K. Harling with sponsorship by the Energy Research and Development Administration. Irradiation damage testing is already in progress. A large interdisciplinary and interdepartmental effort to develop a program in advanced alloys for fusion reactors is also being coordinated by Professor Harling. Efforts to rebuild a good radiochemistry and nuclear activation analysis capability were initiated in the N. R. L. Two new projects have already received funding. Several interdepartmental proposals have also been prepared which involve radiochemistry capabilities in the N. R. L. These projects and proposals are indicative of the broad applicability of these techniques to the research needs of various M. I. T. departments. A senior radiochemist, Dr. M. Janghorbani, has been hired to form the nucleus of the increased research activity in this area. Proposals for other new research projects have been prepared and are being marketed by N. R. L. management. These include a national small angle neutron scattering facility in response to a National Science Foundation request, an in-pile coolant corrosion loop for mitigation of the radioactive corrosion project problem in light water power reactors, and a proposal for the investigation of synergistic helium and displacement damage in fusion reactor materials.

OTTO K. HARLING

Research Laboratory of Electronics (R.L.E.)

The Research Laboratory of Electronics, established at the end of World War II as the Institute's first interdepartmental laboratory, was initially organized to encourage interactions between teaching and research in the Departments of Electrical Engineering and Computer Science, and Physics. Over the years the Laboratory has had projects involving participants from as many as a dozen academic departments. The research groups, which currently number approximately 30, conduct research in three broad areas: communication sciences, general physics, and plasma dynamics.

Research in R. L. E. is primarily conducted by faculty members, postdoctorals, and students. Approximately 90 members of the faculty are affiliated with the Laboratory, working with about 275 graduate students and 125 undergraduates. The research spans a spectrum of topics, thus providing opportunities for a wide variety of student theses. During the past year, work in the Laboratory provided the basis for 20 doctoral, 1 engineer's, 20 master's, and 22 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 other agencies of the Department of Defense, the Energy Research and Development Administration (ERDA), the National Science Foundation (NSF), the National Institutes of Health (NIH), and the National Aeronautics and Space Administration (NASA).

GENERAL PHYSICS

The Laboratory's research in general physics involves studies of atoms, molecules, and condensed matter. A few of the research topics in this area are as follows:

Professor John G. King and his associates have continued their development of molecule microscopy. Use of an electron beam to produce localized desorption of neutral small molecules from model biological surfaces has been investigated. Dr. Dusan G. Lysy has demonstrated sample specificity, as a basis of contrast in molecule microscopy, in his studies of the thermal desorption of water molecules from a series of biopolymer surfaces. Apparatus for the study of spatial variations in permeability of surviving tissue is now being tested, and related experiments are well under way at Boston University Medical Center. Dr. James C. Weaver and colleagues have extended the volatile enzyme product method to the assay of enzymes and cells, with many potential applications evident in biomedical research, clinical analysis, and environmental monitoring.

In another direction, one of Professor King's students has found evidence of magic number effects in small drops, containing fewer than 100 He⁴ atoms. They are planning extensive experimental and theoretical investigations of these interesting systems which, apart from atomic nuclei, are the only known small quantum fluid system.

During the past year, Dr. John W. Coleman and his group completed the development of the Auger Electron Microscope (AEM) and began work using it to study impurity atoms in Si and GaAs. Interest now centers on the following questions: sharpness of boundaries

separating low-refractive-index components from high-refractive-index components in integrated optic devices, and regions of different doping in integrated electronic circuit structures; and semiconductor-encapsulant profiles at interfaces. Studies such as these will help determine the effects of anneal-producing defects on the optical and electrical properties of the semiconductor material.

Professor David E. Pritchard and students Riad N. Ahmad and Walter Lapatovich have made a supersonic molecular beam source in which the free expansion of a high pressure gas into a vacuum results in dramatic cooling of the gas. Temperatures on the order of one degree Kelvin have been observed in an expansion of Ne gas seeded with Na, low enough to result in the formation of weakly bound NaNe molecules. The molecular spectrum of these molecules has been studied using a high resolution tunable dye laser in conjunction with an interferometric wavelength measuring device. The spectra are being interpreted to yield highly accurate interatomic potentials for NaNe. NaNe is bound by only $5.8 \pm .7 \text{ cm}^{-1}$ (less than 1 meV). This is the most weakly bound molecule ever studied in a molecular beam.

The NaNe potential curves are relevant to a wide collection of phenomena involving collisions of Ne with Na in its ground and excited states. Examples include the core and far wing line broadening of the Na D line by Ne, the wavelength redistribution of yellow light scattered from Na in a Ne environment (a problem of relevance in stellar atmospheres), the diffusion of Na in Ne, and a host of collision processes involving excited state Na. Professor Pritchard's data will permit the first clear-cut test of theories describing these processes.

Professor John D. Joannopoulos is performing studies of the electronic excitations at surfaces of semiconductors. The effects of relaxations, reconstructions, defects, and adsorbates are being examined. A new theory of metal-semiconductor interfaces is also being developed.

Professor Jin Au Kong and his students have pursued a number of projects in electromagnetic wave propagation and radiation, including: 1) geophysical subsurface probing and communication with dipole antennas, 2) microwave remote sensing of the earth, and 3) fiber optics and integrated optics. Seven journal articles, eight meeting presentations, and several technical reports have been published in the past year.

Professor Hermann Haus and two of his graduate students are working on modelocking of semiconductor lasers in an effort to achieve pulses of picosecond duration in laser systems with potential for integrated optical circuits. Theories of modelocking developed by the group are used to guide the design of such systems. In another project, new modes of surface acoustic wave grating resonators have been discovered theoretically. The modes are now being explored experimentally, in a cooperative effort with a group at the Bell Laboratories, Holmdel.

Professor F. Read McFeely and his group have been working on the design and construction of the photoemission apparatus to perform angle-resolved X-ray photoemission measurements under ultrahigh vacuum conditions. They have also designed and constructed an ultrahigh vacuum, variable-angle, variable temperature probe to operate in conjunction with the Department of Chemistry's Hewlett-Packard photoelectron spectrometer.

Professor McFeely's other major effort has been the construction of a photoelectron spectrometer specifically designed for the study of solid surfaces. This apparatus will employ UV and ultrasoft X-ray photon sources. The spectrometer is rotatable, includes a multichannel detection system, and a computer designed entrance lens system. This instrument will be a unique new tool for angle-resolved photoemission spectroscopy.

During the past year, Professors Alan H. Barrett and Philip C. Myers and graduate students have continued their studies of microwave spectroscopy of the interstellar medium. Dark

interstellar clouds, dark globules, infrared sources, and molecular clouds have been studied via transitions of formaldehyde, carbon monoxide, carbon monosulfide, methanol, ammonia, hydroxyl, hydrogen, and water, using telescopes at Haystack Observatory, the National Radio Astronomy Observatory, and Arecibo Observatory in Puerto Rico. These studies yield information on the chemical, physical, and evolutionary properties of such clouds. Specific projects have included: a comparative study of dust globules in millimeter wave spectral lines; observations of the Taurus dark cloud in transitions of ammonia, carbon monoxide, and atomic hydrogen; and observations of the Rho Ophiuchi dark cloud in seven molecular transitions.

Professors Barrett and Myers and their graduate students have also made studies, with microwave radiometers, of subsurface temperature anomalies in the human body. A pilot program at Faulkner Hospital uses these instruments in the detection of tumors of the breast. Preliminary results indicate cancer detection rates of about 70 percent, a figure comparable to those for infrared methods. When the microwave and infrared methods are combined, the cancer detection rate increases to about 90 percent, a rate comparable to that of the X-ray method (mammography), but with no risk to the patient.

Dr. Ralph H. Staley and his group have initiated a program to chemically modify semiconductor surfaces to produce very low or very high work functions. During the 1976-77 academic year, an apparatus was constructed which will be used to prepare samples under ultra-high vacuum conditions and measure their work functions photoelectrically. Procedures for chemical modification of surfaces using wet chemistry have also been developed.

Professor Frederic R. Morgenthaler and colleagues are engaged in the development of new forms of magnetically-tunable high-Q microwave filters. The work is based upon observations, recently reported by Professor Morgenthaler, of localized, unusually sharp resonances in bulk single crystal yttrium iron garnet (YIG) slabs. In existing devices, the whole sample resonates in phase, and requires uniform internal fields. By contrast, the new approach offers the possibility, through appropriately shaped nonuniform internal fields and localized excitation, of combining several distinct filter elements in one bulk single crystal sample. These elements may be tuned to the same or different frequencies. Techniques involving shaped external pole pieces, chemical doping, ion implantation, and mechanical deformation of the crystal are being employed to provide the required field profiles.

On the theoretical side, a detailed study of magnetic wave propagation in such crystals has been initiated. Preliminary calculations by Professor Morgenthaler reveal special families of field profiles that create bound waves, describable with simple analytic expressions. These solutions provide estimates of those field parameters required to force waves to propagate in desired frequency ranges.

Professor Shaoul Ezekiel and his group are developing a new laser inertial rotation sensor using a passive ring cavity. Preliminary data shows that the sensor is free from problems encountered in conventional laser gyroscopes and should find applications in precision navigation, measurement of earth wobble, and fundamental experiments in general relativity and atomic physics.

Professors Robert J. Birgeneau, David Litster, and Visiting Professor Jens Als-Nielsen have provided the first experimental verification that a one-dimensional density wave system is realized in nature in the form of a smectic liquid crystal. They have carried out a high resolution X-ray scattering study of a smectic liquid crystal and find that the normal Bragg peak in the scattering cross section does not occur. Instead a power law singularity, related to the logarithmically diverging fluctuations, is observed.

Professor Daniel Kleppner, in collaboration with Dr. Ted W. Ducas and students Michael G. Littman and Myron L. Zimmerman, have carried out field ionization studies on highly excited

sodium atoms. The results are in good agreement with theory under certain conditions, but also reveal a variety of unexpected phenomena which suggest the need for major revision of the theory. Aside from its intrinsic interest, field ionization is important because it is being increasingly employed as a detection technique in atomic spectroscopy.

A new technique for observing inelastic scattering processes in excited atom collisions has also been developed by Professor Kleppner and graduate student William D. Phillips. By combining crossed atomic beams techniques with a tumble dye laser, fine-structure state-charging collisions of sodium with various rare gases have been observed as a function of collision energy. This technique provides useful information on collision dynamics. The results confirm theoretical expectations for certain sodium-rare gas systems, but suggest that there are difficulties with others.

Professor Rainer Weiss and his students have continued measurements of the large-scale anisotropies of the primeval cosmic background radiation in the spectral region embracing the black body peak of a 3°K source. The radiation is isotropic to 0.1 percent on angular scales of 17 degrees and larger. The limits set on a global dipole anisotropy indicate that the velocity of the earth relative to the most distant universe is less than 350 km/sec. Galactic dust emission is a major "noise" source in the data. Work has also begun on the COBE satellite which is intended to make the definitive measurement of the spectrum and large-scale angular anisotropy of the cosmic background radiation as well as set limits on the diffuse infrared background between 300 to 8 microns. The satellite is scheduled for launch in 1983.

The activities of Professor Bernard F. Burke and his group have emphasized the study of galactic structure, the interstellar medium, interstellar masers, and discrete radio sources.

Water vapor masers are known to vary, but the "turn-on" sequence had until now not been observed. For the first time, a complete history of the variation of one such maser, in W3OH, was carried out when the "turn-on" was discovered by Aubrey D. Haschick and Professor Burke. One of the 1.35 cm water lines in the complex brightened by a factor of two over eight days, stayed at a maximum for a few days, and then diminished over the succeeding two weeks. The time scale should aid in understanding the pumping mechanism and geometry of the interstellar masers, which are almost certainly related to star formation at a very early stage.

Robert C. Walker has completed the analysis of Very-Long-Baseline Interferometry studies (VLBI) of a number of interstellar H₂O masers. The data were gathered by a five-station experiment spanning the United States, and show that there is velocity structure within the masers that strengthen the concepts of the complexes being related to star formation.

The recent major thrust in remote sensing research has been evaluation of data from the Scanning Microwave Spectrometer on the Nimbus-6 satellite. This instrument was launched in June 1975 and produces images of meteorological variables such as humidity and atmospheric temperatures. It was proposed by a team including Professors Barrett, David Staelin, and Norman Phillips, together with co-investigators from other institutions. This new technology is being applied in operational meteorological satellites now under construction elsewhere.

Analyses and field experiments by Ph. D. candidate Michael Shao and Professor Staelin have indicated that stellar separations can be measured with $\sim 10^{-4}$ arc sec accuracy by means of a two-color tracking astrometric interferometer. Such accuracy is sufficient to detect Jovian planets circling nearby stars, if such planets exist. Work on a prototype instrument has begun.

PLASMA DYNAMICS

A major goal of the plasma dynamics program is extension of our understanding of phenomena in ionized gases. This work has applications in such problems as controlled fusion, space physics, and astrophysics. 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 involve measurements in various portions of the electromagnetic spectrum (microwave, millimeter wave, infrared, optical).

Professor Bruno Coppi, Dr. Ronald R. Parker, and their associates have achieved new record values for the combined particle density and energy confinement time of thermonuclear plasmas produced in the Alcator device.

The Alcator experiment has, in fact, made possible the investigation of new plasma regimes, which are of basic interest for an understanding of the physics of high-temperature plasmas and at the same time represent important steps toward the goals of controlled thermonuclear research. The basic philosophy for this experiment is to create plasmas capable of carrying large currents and current densities, in order to produce conditions where plasma heating results either from (discrete) particle-particle collisions, at relatively high plasma densities, or from collective effects (microinstabilities) at relatively low plasma densities. The Alcator experiments are a joint venture of R. L. E. and the Bitter National Magnet Laboratory.

The Rector Confinement Device developed by a collaboration involving Professors Coppi and Robert Taylor has produced reliably toroidal plasma equilibrium with non-circular cross section. For the first time non-circular isobaric plasma surfaces have been measured by Thompson scattering experiments so that a detailed comparison with theoretical predictions has become possible.

Versator II, a new research tokamak, constructed by Professor George Bekefi and his group, began operation on May 2, 1977. This device is the most flexible of its kind, and will be used to test various radio frequency heating mechanisms for plasmas. In the first series of experiments, 50 kilowatts of microwave power at 800 megahertz will be injected into a plasma at lower hybrid frequency.

A second series of measurements will use 200 kilowatts of power at a frequency of 36 gigahertz, to excite the electron cyclotron frequency.

The theoretical plasma group of Professor Abraham Bers continues its studies in nonlinear wave phenomena in plasmas. Self-modulation, soliton formation, and the onset of stochastic particle motion in coherent plasma waves in a magnetic field have been investigated during this past year. Studies within this group have progressed to the point where experiments for testing the feasibility of heating tokamak-type plasmas with high-power microwave sources can be designed in detail. This work will be used directly in proposing experiments to heat the plasmas in Alcator A and C, in Versator II.

A new positive ion (H^+ or D^+) source, capable of producing ion beams of 30-50 amps, has been designed and tested by Professor Louis D. Smullin and his group. It is about five times more power efficient than existing sources; its high impedance input ($\sim 1,500$ V to 30 amps) is a significant advantage over the low impedance (~ 50 V to 5,000 amps) of existing devices. These sources are essential elements in the production of powerful neutral beams required to heat magnetically confined plasmas to the "ignition" point for controlled thermonuclear power generation.

COMMUNICATION SCIENCES AND ENGINEERING

This research covers 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 applications, such as speech and picture transmission, seismic detection, and optical communication. Much of the effort is related to the life sciences. A combined program of research and training in communications bioengineering includes communications biophysics, neurophysiology, cognitive information processing, and speech communication. Much of this work concerns the sensory or perceptual mechanisms. A related program in linguistics seeks to improve our understanding of languages, which form the basis for communication.

The research of Professors Robert S. Kennedy, Jeffrey H. Shapiro, Dr. Horace P. Yuen, and their students, is concerned with the extension of communication theory to optical frequencies. It involves a variety of new issues related to the characteristics of communication channels and optical devices. The spatial and quantum mechanical behavior of optical fields are particularly important in these investigations. For example, the fundamental questions of detection, estimation, and modulation are found to be questions of quantum state generation and quantum measurement. Abstract studies of these questions have led to theoretically optimum systems. Also, newly developed statistical characterizations for optical propagation through random communication channels, such as the turbulent and the turbid atmosphere, have been used to determine the way in which the space-time variations of the received optical field should be processed by a receiver. This work has led to some potentially useful receivers that adaptively compensate for the spatial and temporal field variations caused by the channel.

In carrying out a study of the noise in nonlinear devices under the conditions of small steady excitation, Professor Madhu S. Gupta has derived a new general result, which is an extension of the well-known Nyquist Theorem. Attempts to generalize and establish the range of applicability of this result are elucidating the fluctuation phenomena in nonlinear systems.

The cognitive information processing group, under the direction of Professor Ian T. Young, has continued its studies of image enhancement, image restoration, image measurement, and image interpretation. Professor Young, Dr. Samuel Latt of Children's Hospital Medical Center and Harvard Medical School, and Gregory Zack, a graduate student in the Department of Electrical Engineering and Computer Science, are also doing research on automated detection and estimation of sister chromatid exchanges of newly replicated DNA in human metaphase chromosomes. The exchanges, which are a sensitive indicator of environmental chemicals, may provide an index of the carcinogenicity and mutagenicity of various compounds. Computer processing, at speeds much greater than that achievable by humans, offers the possibility of detecting low-level effects that might otherwise go unnoticed.

The "electronic darkroom" project, conducted for the Associated Press by Professor Donald E. Troxel and his students, will be installed at the Associated Press headquarters in New York this summer. Pictures are automatically stored and transmitted from a computer. At the same time, the editor can electronically enlarge, reduce, crop, combine, and enhance pictures, as well as add captions.

Professor William F. Schreiber and his group have developed a digital facsimile system for high fidelity transmission of medical X rays. Full size films, ready to use, are produced by the receiver after transmission over a communication line or subsequent to computer processing.

Professor Jonathan Allen and his co-workers have demonstrated intelligible and natural-sounding synthetic speech obtained from a wide variety of texts. The quality of the speech is suitable for reading machines for the blind and computer aided instruction. Emphasis is now being placed on efficient implementations. For several modules of the system, specialized computer architectures have been devised and simulated, leading to prototype processors. Each of these architectures reflects the basic structure of the associated algorithms, so that the resulting digital design is very efficient in both space and time.

Professors Alan V. Oppenheim and James H. McClellan, with several graduate students, have developed a number of new digital signal processing techniques, and applied them to speech processing and seismic data processing. The speech processing work is directed towards low-cost speech compression and enhancement of degraded speech (as experienced, for example, on a faulty communication channel). The seismic data processing studies have led to new techniques potentially useful for exploration seismology.

Research on speech communication, under the direction of Professor Kenneth N. Stevens, includes studies of both normal and impaired speech production and perception processes. There has been increased emphasis on studies of the phonetic aspects of sentences, particularly the description of acoustic markers that indicate the syntactic structure of a sentence. These acoustic markers include timing, contour of fundamental frequency, and other phonetic modifications of the segments in a sentence, such as those occurring across word boundaries. The insights gained in these studies are being used to improve the quality of speech that is produced in a system for speech synthesis by machine, and also to elucidate the influence of timing inadequacies on the intelligibility of the speech of deaf persons.

Research in the Auditory Perception Group by Nathaniel I. Durlach, Steven Colburn, and Professor Louis D. Braida continues to focus on intensity perception and loudness, binaural interaction, and aids for the deaf. In the first area, they have begun experimental tests of a new theory of loudness comparisons for the case of tones presented in quiet and noisy backgrounds. In the second, they have refined their model of binaural interaction by restricting the allowable decision variables, computed from auditory-nerve firing patterns, to a small set related to subjective lateral position, pitch, and loudness. In the third, they have begun to evaluate multiband amplitude compression systems for persons with reduced dynamic range, frequency lowering techniques for persons with severe losses at high frequencies, and tactile displays for listeners with no useful residual hearing. Included in the last project is an analysis of the TADOMA method of speech reading, used by certain deaf blind persons, in which speech information is obtained by manually monitoring actions associated with the speech articulation process.

Among the works of the Neurophysiology Group in R. L. E. under the direction of Professor Jerome Y. Lettvin have been the following:

Dr. Stephen Waxman and his collaborators have designed a new stain for active versus inactive membrane in myelinated nerve. This development will be useful in the study of demyelinating diseases, such as multiple sclerosis. They have also studied models, the effects of demyelinating disease and of pharmacologic agents on myelinated nerve. The results correlate very well with computer models of the process.

Dr. Stephen Raymond has devised a novel and extremely sensitive measure of the moment-to-moment threshold of a nerve fiber over as long a time as 72 hours. With this system, Dr. Raymond can do basic studies of membrane processes; he can also fingerprint the action of different neurotropic drugs in concentrations known to occur in humans.

Professors Lettvin and Humberto Maturana have found a formal basis for the perception of texture by type II fibers of the frog's eye. Professor Lettvin alone has devised a working

analogue model for the rods and cones of the eye; the model predicts several psychophysical laws successfully.

Professors Lawrence S. Frishkopf and Charles M. Oman continue to investigate mechanisms of sensory transduction in lateral line and vestibular organs of fish and amphibians, using physiological, histochemical, and anatomical methods. An upper limit on the displacement of the cupula, in the semicircular canal of an elasmobranch fish, has been estimated. In collaboration with Professor Thomas F. Weiss, Dr. Claude Lechene of Harvard Medical School, and graduate student Scott K. Peterson, the composition of the labyrinthine fluids has been measured in several vertebrate species.

Professors Weiss and William T. Peake, Dr. John J. Guinan, Jr., and their students are working toward the development of diagnostic techniques for neurological and otological disorders. The clinical aspects of this research were carried out in collaboration with clinicians from the Massachusetts Eye and Ear Infirmary and Massachusetts General Hospital.

Research in linguistics has continued at the usual pace and as in the past year has dealt with all areas of language.

Professor Noam Chomsky's research has concentrated on studying the effects of a radical restructuring of the descriptive devices of linguistics. In particular, he has attempted to eliminate the great richness and variety of transformational devices postulated in earlier work in favor of an extremely limited system of surface filters, and has found that this impoverishment of the available descriptive devices does not affect the system's ability to reflect adequately the relevant linguistic data. In fact, the limited system provides explanations for a number of well-known but hitherto puzzling cross-linguistic uniformities, such as the restrictions on the questioning of sentential subjects in widely differing languages, and certain quite intricate properties of infinitival constructions. Moreover, many specific properties of transformational rules can be explained on the basis of independently motivated principles of anaphora, through the medium of a specially developed "theory of traces," and on the basis of independent principles governing logical form.

Professors Chomsky, Morris Halle, and Dr. Mary-Louise Kean took part in a workshop on the biological foundations of language. This workshop, which met at M. I. T. in 1975 and 1976, attempted to survey and rethink much of the accumulated information on the biological aspects of language from the perspectives of the latest advances in linguistic theory, with the aim of laying the foundations for a comprehensive program of research in this area. The final mimeographed report of this workshop was published early in 1977. This workshop was supported in part by a grant from the Alfred P. Sloan Foundation. A new grant of modest size has just been approved by the Sloan Foundation to be used for further explorations in this area.

The major focus of Professor John R. Ross's research this year has been the extension of his investigation of sounding laws -- the phonological principles that determine such "Siamese" words as helter-skelter, namby-pamby, etc. -- to the study of poetry. It seems that some poets do make use of these laws systematically (though the same poet may use the same laws in opposite directions in two different poems). What the function or meaning of compliance with or disobedience of these laws in any given poem is at present not clear to him.

PETER A. WOLFF

Undergraduate Research Opportunities Program (UROP)

This was the Undergraduate Research Opportunities Program's eighth year. In May UROP received the Irwin Sizer Award, presented by the Graduate Student Council, for the "most significant improvement to M. I. T. education." UROP has developed as an outgrowth of the tradition of undergraduate access to Institute research activities through senior theses, project laboratories, and special problem subject numbers. The Program has succeeded in broadening this access to include activities of all of the academic departments and many of the Institute offices; in catalyzing intellectual collaborations involving faculty, graduate students, and non-M. I. T. professionals; and in easing the tension often felt between educational and research efforts. As a vehicle for creating and promoting professional development of undergraduates, UROP has concomitantly found itself a vehicle for encouraging academic and technical innovation, and faculty as well as institutional professional growth and development.

UROP financial and staff support extends well beyond those students formally acknowledged as UROP participants. Funding for new internship programs sponsored by the Departments of Political Science and Urban Studies and Planning was shared by these departments and UROP. A new laboratory in the Department of Architecture, the Visible Language Workshop, received materials through UROP grants to its undergraduate research staff. Students extending term-time cooperative programs with nonprofit agencies and governmental agencies received partial UROP support to continue summer projects. In response to an increasing number of incoming M. I. T. freshman requests for information on UROP and how to become involved during the summer before they enter M. I. T., summer project participation was made available through UROP to students involved in Interphase, the summer pre-freshman academic program.

Seeking to build on the desire of students to present their research to others and to learn about work other undergraduates are doing, and to encourage students to learn to speak "on their feet," the Departments of Physics, Chemistry, and Nutrition and Food Science hosted undergraduate research symposia. UROP itself presented three symposia: two were "sampler" programs, with a total of 12 students speaking; the third symposium, entitled "Undergraduate Research in Medicine: Projects in Boston Hospitals," involved six students who are participating in front-line research within hospital laboratories. In addition, UROP received monies from the Alfred P. Sloan Foundation to produce several M. I. T. cable TV programs. Four pilot programs have been developed so far. These, and future programs, are available to alumni, prospective freshmen, and other interested groups.

With regard to numerics, participation by undergraduates continues to include more than half the current undergraduate student body. Eight out of 10 students are likely to participate in undergraduate research by the time they finish their four-year program. A steady number of students participate in research opportunities beyond the campus. Well over 200 students undertook projects in the Boston area this year (the fifth year of off-campus UROP). Some 150 of these students worked in medical settings, which continue to be a primary area of interest for students wishing to do research outside M. I. T. Other work off campus was carried out at 35 different nonprofit organizations, industries, museums, and governmental agencies. Interest was noticeably strong in both environmental research and computer technology.

In addition to general funds, monetary support for undergraduate research was provided by grants to UROP from: the Uniroyal Foundation; COMSAT, MITRE, and Draper Laboratories in memory of James McCormack; the Society of Sigma Xi; M. I. T. 's Class of 1970; the Clapp and Poliak Fund; and the MacGregor Fund. The Society of Sigma Xi not only continued their awards for materials and services, but established new awards that will support student initiated research. One award will be reserved for the School of Science and one for the School of Engineering. In addition to these new grants, UROP assumed major responsibility for the Eloranta Fellowships which are awarded each summer to undergraduates. Over one million dollars of funding was administered by UROP in 1976-77, including support from off-campus organizations and that offered by faculty from research contracts. The willingness of faculty to support research expenses of undergraduates continues to grow and will be an important component of conceptualizing UROP's continuing evolution.

Over the years, UROP has influenced the College Work-Study Program, student employment, and overhead operations and policy. For example, UROP overviews of legal agreements, senior thesis operations, medical insurance applicability, the Institute calendar, and academic accreditation guidelines for student research activity often became Institute policy "as-is," or lay the foundation for discussion of future policy. The time is probably overdue for UROP to cease being categorized as a program, and instead to be recognized and understood as an office. The difference in perception will be critical as UROP reaches full maturity.

MARGARET L. A. MACVICAR

Patent and Copyright Office

The Patent and Copyright Office seeks to serve the M. I. T. community through protecting and promoting the traditional academic freedom of the Institute's staff and students in matters of publication, and to promote the progress of science and the useful arts by utilizing the benefits of the established patent system in a manner consistent with the public interest.

During the past fiscal year, 149 invention disclosures were received, 80 US patent applications were filed, and 37 US patents issued. Additionally, 87 patent applications were filed in foreign countries corresponding to 23 US applications. Gross royalty income from patent and copyright licensing totaled \$976,053.80. Our estimated net income of \$647,436 represents an increase of 49 percent over the past year's net income.

Organization

Since January 1, 1977 the M. I. T. Patent and Copyright Office has reported directly to the Vice President for Research, who also serves as Chairman of M. I. T. 's Committee on Inventions and Copyrights. Additionally, funds have been allocated for a marketing capability operating out of the Office of the Vice President for Research and for a general legal assistant within the M. I. T. Patent and Copyright Office. It is anticipated that the reorganization will enhance our efforts to transfer M. I. T. 's technology to the public, while at the same time encouraging individual research efforts through the realization of royalty-bearing licenses.

Government Patent Policy

The success of the patent program at the Institute is greatly dependent on the direction and volume of Government sponsored research and on its various patent policies. Over the past 10 years, we have seen the emergence of substantial National Science Foundation (NSF) and National Institutes of Health (NIH) support of Institute research. This has somewhat supplanted our past reliance on Department of Defense and National Aeronautics and Space Administration funding. Recently, the volume of Energy Research and Development Administration (ERDA) sponsored research has increased dramatically. In the case of NSF and NIH, the Institute was successful in negotiating Institutional Patent Agreements which allow M.I.T. to retain title to inventions. The number of inventions arising from such sponsored research and on which M.I.T. filed patent applications increased proportionately to the increase in their support. In the case of ERDA, however, all inventions arising from ERDA sponsored research remain the property of that agency unless M.I.T. is successful in petitioning for a pre-award waiver for rights in the Institute. However, we anticipate a change in ERDA policy to allow some form of modified Institutional Patent Agreement for qualified educational institutions.

Presently the Government is studying in depth the feasibility of formulating a uniform government patent policy. The M.I.T. Patent and Copyright Office believes that the implementation of such a uniform policy would greatly stimulate the transfer of technology to the public by utilizing the patent system in conjunction with the resources of the private sector to develop and market the results of sponsored research.

Special Projects

In addition to its normal responsibilities, the M.I.T. Patent and Copyright Office gives legal advice and support to certain special Institute programs such as the Innovation Center and the Polymer Processing Program.

Operating under a grant from NSF, the Innovation Co-op supports and guides students in developing innovative ideas to the stage where they can be presented to industry and/or potential investors for assessment. Students undertake prototype development, experimental fabrication, patent application, market analysis, and promotion of new products, processes, and services. The M.I.T. Patent and Copyright Office assists the Co-op by filing and financing patent applications on their inventions and by aiding the manager of the Center in negotiating and preparing license agreements. To date we have filed 14 US and 15 foreign patent applications. In fiscal year 1977, royalty income generated \$16,900 towards the continued operation of the Center, in addition to royalties payable to the student inventors.

The M.I.T. -Industry Polymer Processing Program is an experimental attempt to establish an industry-university, cooperative research program supported in part by incentive funding from NSF and the membership fees of the industrial participants. The M.I.T. Patent and Copyright Office interacts with the Industrial Advisory Council of the Program in resolving areas of concern relative to the issues of patent rights, handling of proprietary data, and licensing policy. To date we have filed nine US and 40 foreign patent applications, and are presently negotiating with potential licensees. In this regard the M.I.T. Patent and Copyright Office serves as the legal representative for the Program participants.

Copyrights

The Institute has for some time now had a reasonable and workable copyright policy which generates royalty income from copyright licenses to the Institute, the author(s), and the

departments, while protecting the academic freedom of its staff and students to publish freely without restriction. However, on October 19, 1976, Congress passed Public Law 94-553, extensively revising the Copyright Law Title 17 of the United States Code. This law becomes effective on January 1, 1978 and appears to affect to some extent the Institute's traditional posture towards publication, fair-use copying, and copyright equity considerations. An ad hoc committee to investigate the repercussions of the new law on the Institute's copyright policies and procedures is currently being organized.

ARTHUR A. SMITH

Lincoln Laboratory

This spring, Dr. Gerald P. Dinneen accepted President Jimmy Carter's nomination to become Assistant Secretary of Defense for Command, Control, Communications, and Intelligence and resigned as Director of Lincoln Laboratory, a position he held with great distinction for almost seven of his 24 years at Lincoln. Last November, at a ceremony marking the Laboratory's 25th year of service to the nation, Chancellor Gray aptly noted Dr. Dinneen's "...single-minded concern for quality and excellence, his extraordinary personal knowledge of the Laboratory's programs, sponsors, and people, and his evident concern for the well-being of all who work here...."

On the happy occasion of that ceremony, the Laboratory was honored to receive a Meritorious Award from the Department of Defense, presented by Air Force Secretary Thomas C. Reed on behalf of Defense Secretary Donald Rumsfeld and accepted for the Institute and Lincoln Laboratory by President Jerome B. Wiesner.

Two additional Assistant Directors, Donald C. MacLellan and Dr. John V. Evans, have recently been appointed to help maintain an equitable distribution of authority and responsibility for management of Laboratory programs.

Mr. MacLellan joined the Laboratory in 1957 to work on the development of long-range tropospheric scatter communication systems, and was subsequently responsible for the payload used in the Project West Ford orbiting dipole experiment. Since 1963 he has played a leading role in the development of the Lincoln Experimental Satellite (LES) series. He has been a member of the Lincoln Laboratory Steering Committee since 1972, as Associate Head and later Head of the Communications Division. As Assistant Director, he will be concerned primarily with the Laboratory's satellite communication and energy programs.

Dr. Evans came to Lincoln Laboratory in 1960. He has made substantial contributions to the development of planetary radar astronomy and to the use of incoherent radar backscatter techniques in a long-term study of the composition and dynamics of the ionosphere. In addition, he has been a major contributor to the development of techniques for radar tracking of high-altitude satellites. He has been a member of the Lincoln Laboratory Steering Committee since 1975 as Associate Head of the Aerospace Division. As Assistant Director, he will be concerned with advanced research programs in solid state, data systems, seismology, and space research.

In addition to the programs mentioned above, the Laboratory continues to maintain major efforts in reentry phenomenology, satellite surveillance, millimeter and infrared radar, and tactical technology. Some current activities and recent accomplishments are presented here.

Certainly one of the most significant technical accomplishments of the year has been the successful completion of all major experiments and demonstrations with the LES-8 and LES-9 satellites and associated terminal facilities. These satellites and terminals were designed to demonstrate critical technology for strategic command and control communication systems that must operate dependably, over wide areas, despite determined hostile interference.

The spacecraft use UHF-band frequencies to relay communications among small, mobile terminals, extending techniques developed and demonstrated with earlier Lincoln Experimental Satellites. They also use K-band frequencies above 36,000 megahertz, considerably higher than frequencies previously used for satellite communication. Precisely steerable, narrow-beam K-band antenna systems aboard the spacecraft enable them to establish and automatically maintain a satellite-to-satellite crosslink. Measured crosslink margins are sufficient to provide communication out to an orbital separation of 100 degrees between the satellites, which would provide coverage of more than three-quarters of the surface of the earth without the need for any intermediate ground terminals.

Alternatively, the crosslink antennas can be pointed down toward the earth to provide communication channels supplementary to those afforded by the UHF and K-band antennas that are mounted in a fixed orientation along one axis of the three-axis-stabilized spacecraft. Flexibility in assigning up-link receivers and down-link transmitters to the several antennas provides many communication modes for experimental purposes, for hard-copy teletype and/or voice messages, at a variety of digital modulation rates. For this purpose, a substantial signal-processing capability is built into each spacecraft.

LES-8 and 9, and the terminal and testing facilities associated with them, are the products of more than five years of planning and hard work by some 300 Lincoln people. It is a particular pleasure to report that the satellites and terminals have operated precisely as planned in all major respects and that their communication capabilities have proved to be fully up to expectations. Many of the new concepts and techniques demonstrated in this experiment will find important applications in communication satellites and satellite communication systems in the future.

The Laboratory is continuing to monitor the performance of LES-8 and 9, but operational scheduling and control of the spacecraft will be transferred in the near future to the Air Force Communications Service. Meanwhile, the major focus of the Lincoln space communications program is now being directed at providing flexible, low-cost satellite communications for a much larger number of mobile platforms, such as aircraft, ships, and trucks. Relevant techniques include the use of adaptive multiple-beam spacecraft antennas; demodulation, multiplexing, and remodulation of data onboard the satellite; and a system organization based on demand access.

Another aspect of the Laboratory's broad interest in communication is the digital processing and transmission of speech, which has been the subject of investigation here for many years. In the course of this work, efficient, compact terminals have been developed that will transmit intelligible speech of satisfactory quality at bit rates one-tenth or even one-twentieth of that required for unprocessed speech. It is well known, however, that the performance of such systems is seriously impaired if the speech originates in a noisy environment. One facet of the present program is to seek processing techniques that will resist such impairment. In a separate program, techniques are being investigated for transmitting speech over networks designed for digital data transmission. In this application, the speech must be broken up into short segments (or "packets") and reassembled at the receiver with minimal degradation.

At White Sands, New Mexico, Lincoln Laboratory has been developing a system for optical observation of satellites out to synchronous-orbit altitudes and beyond. The system uses sensitive electrooptical image tubes in conjunction with coupled 14-inch and 31-inch telescopes and can detect transient optical phenomena as faint as 16th or 17th magnitude. The telescopes are pointed automatically at the current predicted position of any desired target; ephemerides of all known satellites as well as the complete star catalogue of the Smithsonian Astrophysical Observatory are stored on computer disk files for rapid access and calibration. On the basis of the results obtained at the Experimental Test Site, the Air Force has received approval to begin procurement of equipment and facilities for a global network of five operational sites as elements of its Ground Electro-Optical Deep Space Surveillance (GEODSS) System for the detection, tracking, and identification of satellites. Lincoln Laboratory will continue to provide technical assistance as needed.

A major new radar system has been completed and will be sharing time at the Haystack Observatory with ongoing radio astronomy observations. The culmination of more than four years of planning and development, this radar was designed to take full advantage of the unique versatility and precision of the Haystack antenna system. Indeed, the multi-purpose utilization of the antenna system was a key feature of the original design when Lincoln built Haystack for the Air Force in 1960-64. The facility was declared surplus to Air Force needs in 1970, when no further specific service requirements for it were foreseen. Since that time it has been operated by M.I.T. primarily for the Northeast Radio Observatory Corporation, with only occasional use for Lincoln projects.

For the new radar system, however, the large-aperture, precision-contour Haystack antenna, with its provision for interchangeable RF electronics, is absolutely essential. At the operating frequency of 10,000 megahertz, the antenna provides a beamwidth of 0.05 degree and an antenna gain of 68 decibels. The transmitter, receiver, and all associated RF equipment are mounted in a box 8 by 8 by 12 feet in size that is hoisted up and fitted into the antenna structure when the radar is scheduled for operation. Cooling water and high-voltage power for the transmitter are provided by existing Haystack facilities, modified as required. All the rest of the radar system -- including wideband waveform generators and signal processors, radar control computer, control consoles, data displays and recorders -- is housed in a new building adjacent to the Haystack radome.

The new radar has a signal bandwidth of 1,000 megahertz, corresponding to a range-resolution of 0.25 meter. Designed to make detailed measurements and observations of satellites out to synchronous-orbit altitudes, it is a very significant advance in space surveillance capabilities.

Two years ago, a digital signal processor developed at Lincoln Laboratory made possible a dramatic improvement in the performance of airport surveillance radars. Using coherent linear filtering with automatic, adaptive thresholding techniques, this processor virtually eliminates ground clutter and weather clutter, enabling the radar to maintain steady, consistent tracks on aircraft under the most adverse conditions.

This new capability offers two promising further prospects, beyond the improved performance of existing airport surveillance radars. First, in the process of eliminating spurious returns, the processor reduces the radar output so substantially that it can be transmitted over a narrow-bandwidth digital circuit. Thus a number of remote radars could readily be netted together to a central computer location for coordination and interpretation, to provide a truly distributed air surveillance system with good low altitude coverage, mobility, and resistance to enemy interference or attack. The second prospect is contributory to the first: since the operation of the processor requires no human intervention, it opens the way to fully automated, unattended radars.

The original processor, designed specifically for use with airport surveillance radars, was not readily adaptable to other radar applications. This year, an equally powerful but much more versatile processor has been developed. Consisting of a number of identical processor modules (as many as may be required for the task at hand), operating in parallel and coordinated by a single control module, it is programmable, expandable, and relatively simple to service and repair. Indeed, in case of a failure in a single processor module, it is capable of self-diagnosis and even self-repair, if a spare module has been provided to take over the task of the faulty one. An indication of the versatility of this new processor is the fact that projects are actively under way, for both military and civilian agencies, to incorporate it into seven different types of air surveillance, ground surveillance, height-finder, and perimeter security radars.

WALTER E. MORROW, JR.

Vice President, Resource Development

PRIVATE SUPPORT

Total private support of M. I. T. during the past year was \$29,423,237, comprising \$26,899,027 in gifts, grants, and bequests, and \$2,524,210 in support through membership in corporate liaison programs (discussed elsewhere in this report). This total is a five-year high, compared with \$23,935,920 received in 1976, \$21,691,646 in 1975, \$22,666,769 in 1974, and \$21,663,396 in 1973. The increased total for 1977 clearly begins to reflect the impact of the M. I. T. Leadership Campaign.

Sources of gifts for fiscal year 1977 were: alumni, \$6,113,209; non-alumni friends, \$3,024,446; corporations, corporate foundations, and trade associations, \$7,751,127; foundations and charitable trusts, \$9,872,156; others, \$138,089. Included in the totals for alumni and friends are gifts of \$130,748 made to the William Barton Rogers Pooled Income Fund, which was inaugurated in fall, 1975. Total income for corporate liaison programs was \$2,524,210, an increase of 33 percent over the total for fiscal year 1976.

Donors designated expendable and endowed funds as follows: unrestricted, \$5,435,847; departments, \$8,146,932; faculty salaries, \$4,607,167; graduate scholarships and fellowships, \$727,054; undergraduate grants, awards, and loan funds, \$1,979,739; building construction funds, \$4,837,001; other funds, \$1,165,291.

M. I. T. LEADERSHIP CAMPAIGN

Campaign Progress

At the end of the year, total commitments to the Leadership Campaign stood at \$132 million, an increase of \$51 million over last year's total, and 59 percent of the Campaign's \$225 million goal. This total of \$132 million included the nucleus fund of \$43 million accumulated between January 1, 1974 and the announcement of the official beginning of the Campaign in April 1975.

Senior officers, together with Campaign Cochairmen, concentrated on contacting top individual, foundation, and corporate prospects with the capacity to make large commitments over a five-year period. Of special importance to the Campaign this year were commitments of \$9 million from the Pew Memorial Trust, \$7 million from The Whitaker Foundation, and \$3 million from the Educational and Medical Fund of the New York Community Trust (a donor advisory fund created by the late U. A. Whitaker and Mrs. Whitaker), all designated for a new facility for health sciences, technology, and management, and a program of medical services. Another special action was a \$3.3 million intention by an anonymous donor to establish an endowment fund for teaching, research, and innovation.

The Volunteer Leadership Appeal (discussed elsewhere in this report) completed organization of 35 areas, brought the total of assigned prospects to more than 2,000, and completed initial solicitation visits to more than 1,200 prospects.

Endowed commitments increased toward the overall goal of \$100 million from year-end totals of \$21.1 million in 1976 to \$30.7 million in 1977, including three additional endowed professorships.

Campaign Organization and Staffing

Howard W. Johnson, Chairman of the M.I.T. Corporation, continued as Chairman of the Campaign. William B. Murphy and Edward O. Vetter, Class of 1942, joined Paul F. Hellmuth, Class of 1947, as Cochairmen of the Campaign. (The detailed organization was described in the 1974-75 Report of the President and the Chancellor.) The Council on Resources of the Institute continued to oversee the Campaign in conjunction with the Campaign Steering Committee. General James B. Lampert, Class of 1939 and Vice President for Resource Development, continued as Campaign Director.

Campaign Steering Committee

During the year, Frank R. Milliken, Class of 1934, Robert B. Semple, Class of 1932, Richard L. Terrell, Class of 1958, and Edward O. Vetter, Class of 1942, joined the Campaign Steering Committee, bringing its total strength to 19.

The Committee met three times this year, in conjunction with Corporation meetings, to discuss Campaign progress, review proposed new efforts and their implementation, and--particularly--augment the key prospect list and explore effective ways to reach the individuals and organizations on that list.

Special Solicitation Efforts

An important Campaign development was the establishment in October 1976 of the National Business Committee (discussed elsewhere in this report). The Committee was created to provide broader and more effective solicitation of corporations.

Special efforts were made on support of solicitations for the Energy Laboratory; the Harvard-M.I.T. Program in Health Sciences and Technology; a new athletics and special events center; a facility for health sciences, technology, and management, and a program of medical services; a major new funding program coordinated by the Council for the Arts; and a number of special professorships.

CORPORATION DEVELOPMENT COMMITTEE

The Committee continued its strong support of the Leadership Campaign through identification of new prospects and approaches to them, solicitation calls, evaluation of Campaign strategy, and efforts on a variety of other matters.

The Committee's Annual Meeting was held on campus on November 5, 1976, with approximately 60 members in attendance. The day-long program consisted of reports from the Chairman, President, Chancellor, and Provost; a progress report on the Campaign; an outline of immediate goals for the Campaign; and panel discussions. Dr. James R. Killian, Jr., Class of 1926, and Honorary Chairman of the Corporation, was the luncheon speaker. Following a luncheon, Cecil H. Green, Class of 1923, was presented with The Marshall B. Dalton Award in recognition of his "exceptional contributions to M.I.T." A reception concluded the day's activities.

Between annual meetings, most of the 155 members of the Committee, including 30 members of the Corporation, were actively involved in specific assignments related to the Leadership Campaign, and contributed their expertise to other M. I. T. committees.

The Committee regrets the death of S. Joseph Tankoos, Jr., Class of 1943, and of former member Dino Olivetti, Class of 1940.

VOLUNTEER LEADERSHIP APPEAL

This year has seen the transition of the Volunteer Leadership Appeal to operational status from the organizational phase described in the 1975-76 Report of the President and the Chancellor.

The Volunteer Leadership Appeal, led by Donald P. Severance, Class of 1938, now has 395 solicitors representing 35 organized areas. Singly, and in teams, volunteers have made one or more solicitation calls on 1,200 prospective Leadership donors, who are generally defined as those who could contribute \$10,000 or more over a five-year period. Ninety percent of these visits were made in fiscal year 1977.

In March 1977, Robert E. Gorman joined James N. Phinney as a district officer in the New York office. This brings to six the number of district officers responsible for field support to senior officers, Campaign Cochairmen, and volunteers.

Although district officers and volunteers identified, solicited, and cultivated corporate and foundation prospects, the emphasis of the Volunteer Leadership Appeal this year was on the solicitation of individual Leadership prospects.

RESOURCE PLANNING

Under the direction of Nelson C. Lees, Resource Planning continued to take principal responsibility for support and planning functions for the Leadership Campaign. Highlights of the year's activities are summarized below.

Development Office

Directed by Dr. Michael F. Luck, the Development Office continued to provide support for the Institute's overall development effort and for the senior officers' Campaign work. The Office, which maintains the central data bank for development at M. I. T., identified and evaluated major donors and prospects, made major visit recommendations, coordinated development contacts by senior officers, deans, faculty, and Resource Development staff, and responded to dozens of weekly queries from sources inside and outside the Institute. Over the year, the Development Office initiated extensive contact with faculty to assist them with their funding priorities.

Assistant Director Richard W. Keefe was given additional responsibility as Special Liaison to the President for the duration of the Leadership Campaign. Associate Director Donald B. Johnson continued to oversee fund-raising efforts directed at philanthropic foundations. Anne K. Mengler, formerly Foundations Analyst, was promoted to the position of Assistant to the Director.

Proposals and Publications

Campaign publications and related proposals continued to be the major responsibility of the Proposals and Publications office, headed by Joseph G. Carr. Over the year, the four-member writing staff was increasingly involved in the preparation of proposals for solicitation efforts by senior officers and by the Leadership Campaign's National Business Committee. The group continued to make good progress on producing various publications detailing Campaign goals, and other material related to the Institute's overall development objectives.

The staff consists of: Patricia M. Maroni, Associate Staff Writer; Ellen N. Hoffman, Assistant Staff Writer; and Deborah J. Cohen, formerly Associate Staff Writer, promoted in January to Senior Staff Writer.

Resource / Alumni Data Systems

The Resource/Alumni Data Systems group, managed by Victor M. Maslov, continued to refine and expand the monthly Leadership Campaign status reports developed in 1975-76. The district officers were provided with a volume of detailed "bio-ledger" information on M.I.T. alumni. The Alumni Fund received data processing support for implementing the "Challenge Gift" appeal.

Robert F. Matson is Systems Analyst. Marina Xydeas replaced programmer Merry Peterson, who left during the year.

Donor Relations

On behalf of senior officers and others, Barbara V. Zeilenga and Martha L. Bertrand drafted approximately 1,700 acknowledgment and cultivation letters to donors. The section further pursued its efforts to foster good relations between donors and the Institute by reporting on the use of previous gifts, including endowment funds; encouraging interaction between staff members and donors, where appropriate; and ensuring that reporting requirements of foundations and corporations were accurately and promptly followed.

Ms. Zeilenga was promoted to Manager, Donor Relations, and Administrative Assistant to the Director. Ms. Bertrand joined Resource Planning in November as Assistant in Donor Relations.

Campaign Room

Under the direction of Jurate J. Barnes, the Campaign Room expanded the operation of the Central Prospect Control System. By year-end, the System contained the names of approximately 3,600 individuals, foundations, and corporations -- an increase of 800 over last year's listing. The Campaign Room provided staff, including all district officers, with regular computer based reports, both on this System and on other systems run in conjunction with Resource/Alumni Data Systems. Statistical analyses of Campaign data were performed for a variety of special and standard reports.

INDIVIDUAL GIVING

Gifts, grants, and bequests from alumni and friends totaled \$9,137,655 this year. The Planned Giving Program, which encourages outright current gifts, gifts in trust, and plans for bequests through individual programs of giving, generated over 40 percent of this total. The table below details the results of the Program.

	Donors	Dollars
Outright gifts generated by Program	24	\$ 373,320
Separately invested unitrusts	6	509,935*
William Barton Rogers Pooled Income Fund	10	130,748
Receipts from bequests, testamentary, and other trust arrangements	55	<u>2,799,827</u>
TOTAL	95	\$ 3,813,830

*Includes \$262,333 given by two donors to unitrusts held outside the Institute.

The Planned Giving Program was reorganized this year to report jointly to the Vice President, Resource Development and the Treasurer of the Corporation. D. Hugh Darden was named Director of the Office of Planned Giving and Legal Affairs/Resource Development, with overall responsibility for the Planned Giving Program.

As of June 30, 1977, there were on record with the Institute 1,055 records or notifications of irrevocable trusts in which the Institute now has a vested future interest or plans for future gifts through bequests. During the year, 33 estates and outside trusts were closed and fully distributed (see table above). Irrevocable trusts totaled 180:

	Number	Dollars (Current Market Value)
Trusts held by M. I. T.	73	\$ 5,667,421
Trusts held outside M. I. T.	<u>107</u>	<u>24,967,799</u>
TOTAL	180	\$ 30,635,220

During the year, two trust funds held by the Institute totaling \$767,282 were closed and transferred over free of trust for Institute purposes.

The year was marked by numerous opportunities to assist donors, senior officers, faculty, and administrative staff, especially Resource Development and Alumni Association staffs, in developing or concluding gift arrangements. Several gift negotiations were initiated which should bear fruit in the near future. In cooperation with the Alumni Association staff, substantial progress was made in developing Reunion gift programs, especially for 40th and 50th Reunion gifts, expanding the theme of cumulative giving as a means of increasing the Institute's gift base among individual donors, and upgrading individual giving.

Substantial time and effort were devoted to providing legal advice and counsel on gift arrangements, internal management, and other matters relating to the Institute's operation. Continuing attention was given to those proposed changes in the Federal tax law or regulatory rules that could affect the Institute adversely, especially in the area of gift support. Some of the provisions of the Tax Reform Act of 1976, particularly those concerning changes in gift and estate tax, may have long-term effects, some of them adverse to charitable giving.

The position of Assistant Director of the Office was vacant over most of the year. As the result of an intensive search program launched in the final quarter, Thomas R. Henneberry was appointed to the position and will assume responsibility early in fiscal year 1978.

FOUNDATION SUPPORT

Gifts and grants to M. I. T. from foundations and charitable trusts during fiscal year 1977 amounted to \$9,872,156, a 48 percent increase over the 1976 total of \$6,704,455.

In connection with the Leadership Campaign, two key pledges were received: \$9 million from the Pew Memorial Trust and \$10 million from the Whitaker Foundations, both to be applied to health and medical related activities at M. I. T.

Staff responsibility for foundation matters in Resource Development remained in the Development Office, under the direction of Donald B. Johnson.

CORPORATE GIFT SUPPORT

Continued economic growth helped to create a favorable climate for the solicitation of corporations. A large number of major proposals was submitted to leading corporations, and many were acted upon favorably.

Corporate support (including Industrial Liaison and Associates programs support) totaled \$10,275,337, compared with \$8,474,102 in 1976, and \$6,913,617 in 1975. This year's total support reflects a 21 percent increase over 1976.

NATIONAL BUSINESS COMMITTEE

In October 1976, the National Business Committee was established to provide a more effective way to reach important corporate prospects for Leadership Campaign solicitation calls. The Committee was chaired by Richard L. Terrell, Class of 1958, Vice Chairman of General Motors. Members of the Committee were: Bennett Archambault, Class of 1932; William S. Brewster, Class of 1939; Thomas F. Creamer, Class of 1940; John H. Gerstenmaier, Class of 1952; Robert C. Gunness, Class of 1934; J. Kenneth Jamieson, Class of 1931; Howard H. Kehrl, Class of 1960; George M. Keller, Class of 1948; Ralph Landau, Class of 1941; John Lawrence, Class of 1932; Frank R. Milliken, Class of 1934; Carl M. Mueller, Class of 1941; W.B. Murphy; Charles H. Smith, Jr., Class of 1952.

The members of the Committee provided introduction to corporate officers; participated on visits; evaluated identified prospects; and helped to guide proposals being placed before the companies. Of 317 new prospects who had not yet been approached (drawn largely from the Fortune 500 list), 157 were assigned to the members of the Committee, and a total of 65 were visited by the end of the year. As a result of Mr. Terrell's suggestion that the Committee be expanded, invitations for membership are now being extended to a considerably larger group. Kenneth S. Brock provided principal support to the Committee, with the able assistance of James T. King, Project Officer; with Mr. Brock's departure, Robert H. Bliss, District Officer, took on the assignment on a temporary basis.

CORPORATE LEADERSHIP AWARD

Resource Development assumed responsibility for determining recipients of a special Corporation award from among a group of alumni candidates who are top officers in major US corporations. Officers of approximately 40,000 corporations were screened. A total of 153 Paul Revere Bowl awards were presented, many at a special luncheon at the Waldorf Astoria on December 3, 1976. Special assistance was provided by the staff of the Development Office, including Mr. King and Alice W. Tripp, Administrative Assistant. Presentation of the award will continue on an annual basis, and will be handled by Resource Development as an ongoing assignment.

INDUSTRIAL LIAISON

During the past year, the Industrial Liaison and Associates programs were combined under the supervision of Samuel A. Goldblith, Director of Industrial Liaison and Underwood-Prescott Professor of Food Science. This merger has enhanced coordination of services and efficiencies of operation. Two liaison officers joined the Industrial Liaison Program staff to maximize interface with faculty and a growing number of member companies. The 13 professional staff members of both programs cover the fields of electronics; electrical, mechanical, chemical, civil, and biochemical engineering; aeronautics and astronautics; materials science; physics; mathematics; nutrition and food science; biochemistry; management; and chemistry.

The following courses were presented under Industrial Liaison Program auspices in Zurich last January: "Research in Polymers;" "Transportation Issues: Techniques for Analysis and Planning;" "Concepts and Methods in the Toxicology of Cancer and Genetic Hazards;" "Mini/Micro Computer Systems;" and "Recent Trends in Signal Processing." Courses on the following topics are being planned for Zurich and London for January 1978: food technology, research and development management, modern control theory, fermentation technology, and micro-processors.

European, American, and Japanese membership in the Industrial Liaison Program continued to grow; a modest office was opened in Tokyo for the 17 Industrial Liaison Program Japanese companies, most of them from the food industry. This growth in membership was reflected in gross income to the Institute; for the first time, the Industrial Liaison Program alone produced a gross of over \$2 million for the year.

The Associates Program grew this year from 38 to 42 companies, with a gross income of \$220 thousand, the highest in the Program's 15-year history.

During recent months, the staff has begun to assist in the Institute's patent licensing program.

Much of the success of Industrial Liaison, both the Industrial Liaison Program and the Associates Program, can be attributed to the splendid and willing cooperation of the senior officers and faculty and the hard work of the staff.

The Associates Program experienced major personnel changes over the year. Jerome J. Schaufeld, Director, resigned in January to take a position in industry; Thomas R. Henneberry, Assistant Director, was promoted to the position of Director. Assistant Director David W. Dove, left in February to assume a position with industry; he was replaced by Cynthia C. Bloomquist, who transferred to the Associates Program from the Industrial Liaison Program. To complete the staffing of the office, Walter Lehmann, formerly Market Planning Manager, Bassick Division, Stewart Warner Corporation, was hired as Assistant Director in March.

JAMES B. LAMPERT

Treasurer

Financial Statements

The financial statements summarize the finances of the Institute during the fiscal year 1976-77 and at the close of the year on June 30, 1977. Schedule F is a new exhibit entitled "Highlights: A Decade in Review," which should prove to be useful in gaining a better understanding of the trends of selected important factors over the past ten years.

Schedule A

The Statement of Revenues and Funds Used to Meet Expenses of Current Operations for the year ended June 30, 1977 with comparative totals for 1976 displays the expenses and the revenues or funds used, categorized as either unrestricted or restricted, and shows the sources of the additional unrestricted revenues and funds needed to meet operating expenses.

Schedule B

The Investment Income for Distribution to Funds for the year ended June 30, 1977 with comparative totals for 1976, reports the year's investment income and other activity in that fund, and details the distribution to funds both in the general investments and in separately invested funds.

Schedule C

The Balance Sheet at June 30, 1977 with comparative totals at June 30, 1976, summarizes the assets, liabilities and fund balances in the major fund categories.

Schedule D

The Condensed Statement of Changes in Financial Position for the year ended June 30, 1977 with comparative totals for 1976, illustrates the changes in total resources resulting from additions, applications, or appropriations during the year, classified between current funds — unrestricted and restricted, and all other funds.

Schedule D-1

The Statement of Changes in Financial Position for the year ended June 30, 1977 with comparative totals for 1976, details the changes in total resources summarized in Schedule D, showing all of the major fund categories.

Schedule E

The Summary of Changes in Invested Fund Balances for the ten years ended June 30, 1977, summarizes the sources and uses of funds each year for the last decade.

Schedule F

The Highlights: A Decade in Review summarizes the several important factors which demonstrate the overall financial position during the last ten years.

The background description of fund accounting emphasized in last year's report, and so important in understanding college and university finances, has been repeated in this report and can be found following the Glossary.

Operations (Schedule A)

Total operating expenses in 1976-77 were \$276,912,000, an increase of 2.8 percent over the 1975-76 total of \$269,250,000. Total operating revenues and funds used to meet these expenses rose to \$271,111,000, an increase of 3.2 percent over the 1975-76 total of \$262,757,000. These figures accurately reflect the accounting for the periods; however the percentage increase between the two years is significantly affected by a substantial drop in subcontracts and purchased materials and services at Lincoln Laboratory from \$40,250,000 in 1975-76 to \$34,379,000 in 1976-77. The total operating expenses increased by 5.6 percent and total operating revenues and funds used increased by 6.1 percent if this factor is excluded. The additional need for unrestricted revenues and funds required to bring operations into balance was reduced from \$6,493,000 in 1975-76 to \$5,801,000 in 1976-77. This requirement in 1976-77 was met almost entirely from current-year revenues of \$1,308,000 from the Use of Facilities Allowances derived from sponsored research programs, \$629,000 from Patent Revenues, and \$3,738,000 from Unrestricted Gifts, Grants, and Bequests for a total of \$5,675,000. All amounts received in these categories were availed of to meet expenses, except for (1) \$340,000 of the Use of Facilities Allowances which was reserved for continuing capital needs, primarily in the area of utility plant renewal and expansion of utility distribution lines; (2) \$83,000 of additional receipts from a single large bequest; and (3) the \$100,000 balance of an unrestricted fund.

The other source used to meet the remaining need for unrestricted funds was \$126,000 of Other Fund Balances which could be drawn upon to support specific activities. This amount came largely from the application of approximately one-fifth of the 1976-77 investment income distributed to the Research Reserve. The Institute was able to retain the other four-fifths of that income to add to the principal of the Research Reserve to offset in part the effect of inflation.

The smaller operating imbalance, and larger unrestricted revenues, primarily unrestricted gifts, grants, and bequests, eliminated the need to use funds functioning as endowment to bring operations into balance. This contrasted with the need to draw down funds functioning as endowment by \$2,610,000 in 1974-75 and \$1,399,000 in 1975-76. The retention and expansion of endowment are vital to the future of the Institute and the favorable results in 1976-77 are an important measure of accomplishment.

The substantial improvement in operating results experienced in 1975-76 continued into 1976-77. Budget reductions in operating expenses continued to be a way of life and an attitude of general restraint and cooperation existed throughout the Institute. The increase in cost was only two percent in the category of indirect expenses jointly applicable to instruction and research, exclusive of plant operations and maintenance. This was well below the level of salary increases and the more general rate of inflation. The 8.5 percent increase in plant operations and maintenance in 1976-77 reflected full-year operation of new buildings and a major program of building renewal and renovations. Revenues used to support campus research increased by 7.9 percent. Tuition and other related income was up by 10.1 percent reflecting again this year increases in tuition rates and fees and in the number of students.

Receipts from the Industrial Liaison Program grew dramatically from \$1,484,000 in 1975-76 to \$2,303,000 in 1976-77, and the M.I.T. Press operations continued to show substantial improvement. The revenues of the Information Processing Center exceeded expenses for the first time since it began charging for services in the mid-1960's. The operating results also benefited from the availability of current unrestricted gifts, grants and bequests totalling \$3,738,000 in 1976-77 as compared to \$2,216,000 in 1975-76. This reflects the success of the M.I.T. Leadership Campaign, and the efforts of the Alumni Fund in its matching gifts program which was initially made possible by the generosity of an anonymous donor.

Gifts

Gifts, grants, and bequests in 1976-77 and in 1975-76 were as follows:

	1976-77	1975-76
Gifts for endowment	\$ 7,137,000	\$ 5,502,000
Gifts for buildings	4,855,000	3,196,000
Gifts for current and future use — invested	5,163,000	4,930,000
Other gifts for current use	5,889,000	4,900,000
Total gifts to funds	<u>\$ 23,044,000</u>	<u>\$ 18,528,000</u>
Grants-in aid	3,855,000	3,865,000
Total	<u>\$ 26,899,000</u>	<u>\$ 22,393,000</u>

The total of \$26,899,000 exceeded the results in each of the past six years. Emphasis by the M.I.T. Leadership Campaign on increasing endowment brought gifts for this purpose to a new high. These gifts included both the initial and continuing funding for several endowed professorships.

The increase in gifts for buildings included new funding for the proposed Health Sciences and Services Center, and funding of previous commitments for the Ralph Landau Building for Chemical Engineering.

The gifts for current and future use — invested included unrestricted gifts of \$3,420,000, of which \$563,000 were bequests. Gifts for future use included \$378,000 in gifts to life income plans where use of the income and principal for Institute purposes is deferred until the termination of commitments to life income beneficiaries.

The gifts reported by the Alumni Fund totaled \$4,851,000, a new high, and are included in the various categories of gifts listed above as received. Grants-in-aid include support for designated sponsored research activities and show almost no change from last year. The other gifts for current use include a portion of the unrestricted gifts, grants and bequests of \$3,738,000 which were used to fund the gap between operating expenses and the revenues and funds used to meet these expenses, as shown in Schedule A. Although these gifts are a recurring source of income, M.I.T. does not normally use them to meet operating expenses. Until recent years, these gifts were transferred to funds functioning as endowment to provide future investment income to the Institute. M.I.T. determines the gap between operating expenses and revenues before the use of unrestricted gifts. Other universities may define their operating gap and the funding of the gap in different terms but we all, in some way, must recognize a continuing need to add unrestricted gifts to permanent resources to assure that future financial resources are adequate.

Funds

The book value of the funds was \$359,356,000 on June 30, 1977 as compared to \$349,643,000 on June 30, 1976.

	1976-77	1975-76
Endowment and similar funds:		
Income for unrestricted purposes		
Endowment	\$ 47,262,000	\$ 46,875,000
Funds functioning as endowment	30,168,000	28,490,000
Income for restricted purposes		
Endowment	87,399,000	80,601,000
Funds functioning as endowment	61,285,000	46,754,000
Investment income for distribution to funds ..	10,000,000	—
Net realized gains from investments	33,542,000	38,472,000
Total endowment funds	\$269,656,000	\$241,192,000
Building and expendable funds	53,996,000	64,083,000
Expended plant funds	169,654,000	167,815,000
Other funds	35,704,000	44,368,000
Total funds	\$529,010,000	\$517,458,000

The increase of \$9,713,000 in funds resulted primarily from the gifts to endowment funds and other gifts retained for investment. Total endowment funds increased because of the net transfer of \$25,091,000 from building and expendable funds and other funds to funds functioning as endowment during the year, detailed in the Appropriations Among Funds section in Schedule D-1. This resulted almost entirely from one transfer to facilitate the longer-term investment of the assets consistent with the nature of the specific funds.

There was a decline in cumulative net realized gains from investments as investment transactions resulted in more losses than gains relative to book values. This decline was due largely to the writedown for book purposes of investments related to real estate that had been written down at market values in earlier years.

There was an increase in building and expendable funds, excluding the effect of transfers described earlier, primarily because of recent gifts for buildings and increased gifts for current use made to the M.I.T. Leadership Campaign. The other funds also increased, excluding transfers, mainly as a result of the continued rise in student loan funds and a moderate addition to the reserve of investment income for distribution to funds.

Funds subject to life interests in income declined due to the transfer of a large fund to the general purposes of the Institute upon the death of the life income beneficiary. This amount exceeded gifts to new and existing life income plans during the year. The Institute reports as its assets only those life income plans established by gifts to M.I.T. A survey was conducted during the year of 106 trusts held outside M.I.T. in which the Institute now has irrevocable vested interests. The total value of the Institute's vested interests in these trusts exceeded \$25,000,000 at market value at the time of the survey and represents an important source of future resources.

Plant

The major renovations and upgrading of the M.I.T. Nuclear Reactor were completed in 1976-77. A further addition to educational plant was the completion of the remaining portion of the third floor of the Seeley G. Mudd Building for the use of the Center for Cancer Research. The extension of the central chilled water system of the Institute has moved forward in the main building complex.

Other plant activities underway include an interim animal care facility on Vassar Street which was necessary as a holding area to enable other work to be done in several buildings housing animals, all of which was required to meet the higher standards for animal care recently set by the Federal government. In addition, a new combustion facility for the Energy Laboratory is under construction and the provision of additional space for the National Magnet Laboratory, the Plasma Fusion Center, and the Energy Laboratory to meet new research requirements is a continuing activity. The construction of the Henry G. Steinbrenner Stadium, which commenced in June 1977, is expected to be completed in the fall. Also scheduled for completion in the fall is the new Alumni Center on the first floor of the Maclaurin Building and the reconstruction of Huntington Hall, one of M.I.T.'s major lecture halls.

The book value of educational plant was \$203,340,000 at June 30, 1977, up from \$201,823,000 on June 30, 1976.

Total mortgage indebtedness at June 30, 1977 was \$31,910,000, consisting of \$10,258,000 of Federal government loans, \$21,178,000 financed through the Massachusetts Health and Educational Facilities Authority and \$474,000 of other loans.

Investments

The year-to-year change in the endowment and other investments is shown in the following table:³

	June 30, 1977		June 30, 1976	
	Book	Market	Book	Market
General investments				
Fixed income	\$146,703,000	\$140,010,000	\$144,237,000	\$125,847,000
Equities	119,172,000	192,175,000	114,164,000	212,041,000
Real estate				
For present or future use	13,437,000	13,437,000 ¹	13,439,000	13,439,000 ¹
Other real estate	30,465,000	31,696,000 ²	29,258,000	30,997,000 ²
Total	\$309,777,000	\$377,318,000	\$301,098,000	\$382,324,000
Separately invested	22,929,000	23,778,000	18,780,000	18,682,000
Total	\$332,706,000	\$401,096,000	\$319,878,000	\$401,006,000

¹ At cost

² At values determined by professional appraisers

³ This table excludes student notes receivable and amounts due from Educational Plant Funds.

There was a modest increase of \$90,000 in the market value of the portfolio in 1976-77, compared with an increase of \$24,945,000 in the market value of the portfolio in 1975-76. A decline in the market value of common stocks was fully offset by higher prices for fixed income securities and by the additions to holdings from gifts and other receipts. Although common stock prices declined, there was a 27.9 percent increase in the income from common stock dividends.

Portfolio transactions and exchanges resulted in net realized losses relative to book values, caused primarily by realizing the loss for book purposes on the Institute's investment in the debentures of the Northgate Community Corporation. This corporation was affiliated with M.I.T. and had been organized to provide student, faculty, staff, and community housing in Cambridge and nearby communities. The market value of these debentures had been written down to zero in 1973-74, primarily because of rent control, higher taxes, and higher operating costs. The real estate holdings had been largely liquidated prior to the assumption of the remaining assets and liabilities by M.I.T. on June 30, 1977.

There was also a loss realized on an exchange of real estate-related securities. In addition, a net loss was realized on the sale of fixed income securities originally purchased during a period of lower interest rates and higher bond prices. The proceeds have been reinvested largely in other fixed income securities at higher coupon rates.

The M.I.T. Development Foundation ceased active operation during the year. Its portfolio of securities in small technology companies, and its other assets, were added to the resources of the Institute.

The total investment income received during the year was \$20,191,000, as compared with \$18,996,000 in 1975-76. After the deduction of administrative expenses, there remained \$19,783,000 of investment income for operating expenses and other purposes during 1976-77. M.I.T. makes available to operations and other Institute purposes only the income from dividends, interest, and rents earned from investments, including internal advances. During 1976-77, the investment income actually earned exceeded the income distributed to funds, as shown in Schedule B. The resulting addition to investment income for distribution to funds was \$188,000 in 1976-77, whereas there was a drawdown of \$593,000 in 1975-76. The balance of investment income for distribution to funds was \$19,582,000 on June 30, 1977 and \$19,394,000 on June 30, 1976.

A statement of investment policy was prepared during the year by the Investment Committee in cooperation with the senior officers of the Institute. It included a reaffirmation of the investment policies that have served M.I.T. well in the past.

The need to maintain capital for future growth was an important factor in the decision to continue to distribute only earned investment income to funds. A procedure has been established for increasing annually the income allocated to funds that is based on longer-term trends. This procedure causes the annual growth of income allocated to funds to more closely approximate the annual effects of inflation on the need for investment income to support operations and other Institute purposes. Unfortunately, the current worldwide economic situation has caused the rate of inflation to be in excess of the expected growth of income from existing investments. This situation is not unique to M.I.T., but does result in a continued need for new financial resources from gifts to maintain existing academic operations. The reserve of investment income for distribution to funds will continue to be used to adjust for the fluctuations in income actually earned in each year as related to the income distributed to funds.

The Investment Committee also expressed a desire to allocate investment returns from assets in a manner that is equitable to both the present and the future needs of the Institute. The development of investment policies and procedures to maintain and increase market values over the long term is of great importance in this process.

General

The overall results of the year and the current projections for 1977-78 are encouraging, particularly in eliminating the need to expend funds functioning as endowment for operating purposes. The development of new endowment and similar funds to strengthen the capital base of the Institute has been successful and continues as a very high priority. We now see the future with cautious optimism, but with the full realization that the problem of keeping ahead of inflation is long term and has no simple solution. The continued success of the M.I.T. Leadership Campaign is vital to maintaining and expanding the Institute's position of leadership and excellence in teaching and research.

Respectfully submitted,

Stuart H. Cowen
Vice President for Financial Operations

Glenn P. Strehle
Treasurer

August 25, 1977

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Statement of Revenues and Funds Used to Meet Expenses of Current Operations
for the year ended June 30, 1977 with comparative totals for 1976
(in thousands of dollars)

Schedule A

	<i>Unrestricted</i>	<i>Institute or Donor Restricted</i>	Total 1977	<i>Total* 1976</i>
OPERATING EXPENSES:				
Instruction and unsponsored research	\$ 28,146	\$ 15,165	\$ 43,311	\$ 40,112
Sponsored research (Note A):				
Direct expenses: (A-2)				
Departmental and interdepartmental	—	77,804	77,804	72,916
Lincoln Laboratory	—	80,503	80,503	84,517
Research administration and general expenses	1,512	36	1,548	1,558
Total expenses directly attributable to instruction and research	29,658	173,508	203,166	199,103
Expenses jointly applicable to instruction and research:				
Libraries	3,305	110	3,415	3,276
Medical	3,586	17	3,603	3,390
Plant operations and maintenance	15,739	1,880	17,619	16,234
Administration	4,975	31	5,006	4,738
Fiscal, personnel and other Institute-wide services	9,463	103	9,566	9,366
General expenses	3,073	1,118	4,191	3,825
Other instruction and research support activities	1,064	113	1,177	1,335
Student services	4,368	1,346	5,714	6,005
Other expenses	2,492	—	2,492	2,679
Scholarships and fellowships:				
Undergraduate	1,427	3,691	5,118	4,582
Graduate	613	4,112	4,725	4,265
Dining and Housing	208	7,414	7,622	7,087
MIT Press	250	3,248	3,498	3,365
Total operating expenses (Schedule D)	<u>\$ 80,221</u>	<u>\$ 196,691</u>	<u>\$ 276,912</u>	<u>\$ 269,250</u>
REVENUES AND FUNDS USED:				
Tuition and other related income	\$ 37,939	—	\$ 37,939	\$ 34,473
Research revenues:				
Departmental and interdepartmental	22,562	\$ 77,804	100,366	93,053
Lincoln Laboratory	7,122	80,503	87,625	92,054
Endowment income applied to operations (Schedule B)	6,438	4,435	10,873	10,301
Gifts, investment income and other receipts for:				
Restricted purposes	—	15,492	15,492	15,406
Scholarships and fellowships	359	7,795	8,154	7,641
Dining and Housing	—	7,414	7,414	6,893
MIT Press	—	3,248	3,248	2,936
Total operating revenues and funds used	74,420	196,691	271,111	262,757
Additional need for unrestricted revenues and funds**	5,801	—	5,801	6,493
Total revenues and funds used	<u>\$ 80,221</u>	<u>\$ 196,691</u>	<u>\$ 276,912</u>	<u>\$ 269,250</u>
**Additional need for unrestricted revenues and funds met from:				
Use of Facilities Allowances	\$ 1,308	—	\$ 1,308	\$ 1,220
Patent Revenues	629	—	629	457
Current gifts, grants, and bequests	3,738	—	3,738	2,216
Total additional current revenues	5,675	—	5,675	3,893
Other fund balances	126	—	126	1,201
Funds functioning as endowment	—	—	—	1,399
Total	<u>\$ 5,801</u>	<u>—</u>	<u>\$ 5,801</u>	<u>\$ 6,493</u>

The accompanying notes are an integral part of the financial statements.

*Reclassified for purposes of comparison.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
INVESTMENT INCOME FOR DISTRIBUTION TO FUNDS
for the year ended June 30, 1977
with comparative totals for 1976
(in thousands of dollars)

Schedule B

	<i>General Investments</i>	<i>Separately Invested Funds</i>	Total 1977	<i>Total 1976</i>
Investment income before distribution:				
Investment income for distribution to funds, balance beginning of year	\$ 19,394	—	\$ 19,394	\$ 19,987
Investment income, current year	<u>18,501</u>	<u>\$ 1,282</u>	<u>19,783</u>	<u>18,532</u>
Total before distribution	\$ 37,895	\$ 1,282	<u>39,177</u>	<u>38,519</u>
Distribution:				
Income distributed:				
From current year's earnings	\$ (18,313)	(1,282)	(19,595)	(18,532)
From prior years' earnings	<u>—</u>	<u>—</u>	<u>—</u>	<u>(593)</u>
*Total distribution to funds	(18,313)	(1,282)	(19,595)	(19,125)
Investment income for distribution to funds, balance end of year	<u>\$ 19,582</u>	<u>\$ —</u>	<u>\$ 19,582</u>	<u>\$ 19,394</u>
Balances include:				
Funds functioning as endowment	\$ 10,000	\$ —	\$ 10,000	—
Current invested funds	<u>9,582</u>	<u>—</u>	<u>9,582</u>	\$ 19,394
Total	\$ 19,582	\$ —	\$ 19,582	\$ 19,394
			(Schedule C)	(Schedule C)
*Total distribution to funds:				
Endowment funds:				
Used for operations (Schedule A)	\$ 10,862	\$ 11	\$ 10,873	\$ 10,301
Used for scholarships and fellowships	2,577	111	2,688	2,708
Used for other charges	48	5	53	5
Added to principal	8	61	69	77
Added to unexpended balances of endowment income	(1)	16	15	(166)
Transferred to other funds	<u>2,949</u>	<u>3</u>	<u>2,952</u>	<u>3,136</u>
Total	\$ 16,443	\$ 207	<u>16,650</u>	<u>16,061</u>
Other funds:				
Agency funds	33	—	33	31
Life income funds	19	336	355	308
Student loan funds	13	—	13	13
Building funds	336	172	508	315
Other expendable funds	<u>1,469</u>	<u>567</u>	<u>2,036</u>	<u>2,397</u>
Other funds	1,870	1,075	2,945	3,064
Total distribution to funds	\$ 18,313	\$ 1,282	\$ 19,595	\$ 19,125

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

BALANCE SHEET

at June 30, 1977

with comparative totals at June 30, 1976

(in thousands of dollars)

Schedule C

	Current Operating Funds	Current Invested Funds	Student Loan Funds	Endowment and Similar Funds	Educational Plant Funds	Life Income and Agency Funds	Total 1977	Total 1976
ASSETS								
Cash:								
Unrestricted	\$ 2,600	\$ —	\$ —	\$ —	\$ —	\$ —	\$ 2,600	\$ 361
Other	2,679	—	—	1,667	119	—	4,465	2,494
Accounts receivable	8,493	—	—	—	—	—	8,493	9,987
Students' notes receivable	—	—	24,554	—	—	—	24,554	21,666
Contracts in progress, principally U.S.								
Government	4,991	—	—	—	—	—	4,991	7,835
Deferred charges, inventories and other assets	13,493	—	—	—	—	—	13,493	9,919
Investments, at cost (Note B)	—	46,154	—	267,959	11,523	7,070	332,706	319,878
Receivables (payables) arising from								
investment transactions	—	—	—	273	—	—	273	614
Due from other M.I.T. funds	6,976	1,743	—	—	—	—	8,719	14,708
Land, buildings, and equipment, at cost	—	—	—	—	200,358	—	200,358	199,656
Construction in progress	—	—	—	—	2,863	—	2,863	2,046
Total assets	<u>\$39,232</u>	<u>\$47,897</u>	<u>\$24,554</u>	<u>\$269,899</u>	<u>\$214,863</u>	<u>\$7,070</u>	<u>\$603,515</u>	<u>\$589,164</u>
LIABILITIES AND FUND BALANCES								
Liabilities:								
Accounts payable and accruals	\$21,847	\$ —	\$ —	\$ —	\$ —	\$ —	\$ 21,847	\$ 15,001
Withholdings, deposits and other credits	5,070	—	—	—	—	—	5,070	6,228
Advances and unexpended grants for								
sponsored research:								
U.S. Government	1,127	—	—	—	—	—	1,127	5,101
Private sources	54	—	—	—	—	—	54	148
Due to other M.I.T. funds	—	6,976	(33)	—	1,776	—	8,719	14,708
Borrowings—Mortgage bonds and								
notes payable (Note F)	—	—	5,535	243	31,910	—	37,688	30,520
Total liabilities	<u>\$28,098</u>	<u>\$ 6,976</u>	<u>\$ 5,502</u>	<u>\$ 243</u>	<u>\$33,686</u>	<u>—</u>	<u>\$ 74,505</u>	<u>\$ 71,706</u>
Fund Balances:								
Expendable:								
Unrestricted purposes	—	—	—	—	—	—	—	—
Restricted gifts and other receipts available								
for current expenses	11,134	—	—	—	—	—	11,134	10,454
Restricted purposes	—	26,810	—	—	—	—	26,810	41,204
Unexpended endowment income for restricted	—	4,529	—	—	—	—	4,529	4,514
purposes	—	—	—	—	—	—	—	—
Investment income for distribution to funds								
(Schedule B — Note D)	—	9,582	—	10,000	—	—	19,582	19,394
Student loan funds (Note E)	—	—	19,052	—	—	—	19,052	17,613
Endowment and similar funds (Note C):								
Income for unrestricted purposes:								
Endowment	—	—	—	47,262	—	—	47,262	46,875
Funds functioning as endowment	—	—	—	30,168	—	—	30,168	28,490
Income for restricted purposes:								
Endowment	—	—	—	87,399	—	—	87,399	80,601
Funds functioning as endowment	—	—	—	61,285	—	—	61,285	46,754
Net realized gain from investments	—	—	—	33,542	—	—	33,542	38,472
Educational plant funds:								
Unexpended	—	—	—	—	11,523	—	11,523	7,911
Expended	—	—	—	—	169,654	—	169,654	167,815
Funds subject to life interests in income	—	—	—	—	—	6,415	6,415	6,734
Agency funds	—	—	—	—	—	655	655	627
Total fund balances	<u>11,134</u>	<u>40,921</u>	<u>19,052</u>	<u>269,656</u>	<u>181,177</u>	<u>7,070</u>	<u>529,010</u>	<u>517,458</u>
Total liabilities and fund balances	<u>\$39,232</u>	<u>\$47,897</u>	<u>\$24,554</u>	<u>\$269,899</u>	<u>\$214,863</u>	<u>\$7,070</u>	<u>\$603,515</u>	<u>\$589,164</u>

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CONDENSED STATEMENT OF CHANGES IN FINANCIAL POSITION
for the year ended June 30, 1977
with comparative totals for 1976
(in thousands of dollars)
Schedule D

	<i>Current Funds</i>			<i>Endowment, Plant, and Similar Funds</i>		
	<i>Unrestricted</i>	<i>Institute or Donor Restricted</i>	<i>Total Current Funds</i>		Total 1977	<i>Total 1976</i>
BALANCES, BEGINNING OF YEAR	\$ —	\$ 75,566	\$ 75,566	\$472,412	\$547,978	\$538,451
Current Year:						
Revenues, other additions, and borrowings .	80,774	199,376	280,150	22,790	302,940	284,260
Operating expenses (Schedule A)	(80,221)	(196,691)	(276,912)	—	(276,912)	(269,250)
Other deductions and repayment of borrowings	—	(1,810)	(1,810)	(5,498)	(7,308)	(5,483)
Net increase (decrease) before appropriations	553	875	1,428	17,292	18,720	9,527
Appropriations among funds	(553)	(24,386)	(24,939)	24,939	—	—
NET INCREASE (DECREASE) FOR THE YEAR	—	(23,511)	(23,511)	42,231	18,720	9,527
BALANCES, END OF YEAR	<u>\$ —</u>	<u>\$ 52,055</u>	<u>\$ 52,055</u>	<u>\$514,643</u>	<u>\$566,698</u>	<u>\$547,978</u>
BALANCES, END OF YEAR INCLUDE:						
Fund balances	\$ —	\$ 52,055	\$ 52,055	\$476,955	\$529,010	\$517,458
Outstanding borrowings	—	—	—	37,688	37,688	30,520
Total	<u>\$ —</u>	<u>\$ 52,055</u>	<u>\$ 52,055</u>	<u>\$514,643</u>	<u>\$566,698</u>	<u>\$547,978</u>

This condensed schedule should be examined in conjunction with the detailed Statement of Changes in Financial Position (Schedule D-1) which follows.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
STATEMENT OF CHANGES IN FINANCIAL POSITION
for the year ended June 30, 1977
with comparative totals for 1976
(in thousands of dollars)

Schedule D-1

	<i>Current Funds</i>		<i>Total Current Funds</i>	<i>Student Loan Funds</i>
	<i>Unrestricted</i>	<i>Institute or Donor Restricted</i>		
BALANCES, BEGINNING OF YEAR	<u>\$ —</u>	<u>\$ 75,566</u>	<u>\$ 75,566</u>	<u>\$ 21,399</u>
REVENUES, OTHER ADDITIONS AND BORROWINGS:				
Tuition and other related income	37,939	—	37,939	—
Research revenues	31,332	158,307	189,639	—
Fees, services and miscellaneous receipts	886	6,214	7,100	473
Investment income	6,550	12,324	18,874	13
Net realized gain or (loss) on investments	1	(8)	(7)	—
Student aid from foundations and agencies	—	4,733	4,733	1,226
Government support for construction	—	—	—	—
Dining and Housing	—	7,414	7,414	—
M.I.T. Press	—	3,248	3,248	—
Gifts, grants and bequests	3,420	7,130	10,550	120
Patent royalties received net of cost	646	14	660	—
Borrowings	—	—	—	5,086
Total revenues, other additions and borrowings	<u>80,774</u>	<u>199,376</u>	<u>280,150</u>	<u>6,918</u>
EXPENDITURES, OTHER DEDUCTIONS AND REPAYMENT OF BORROWINGS:				
Operating expenses (Schedule A)	80,221	196,691	276,912	—
Other deductions	—	1,810	1,810	78
Repayment of borrowings	—	—	—	3,337
Total expenditures, other deductions and repayment of borrowings	<u>80,221</u>	<u>198,501</u>	<u>278,722</u>	<u>3,415</u>
Net increase (decrease) before appropriations	<u>553</u>	<u>875</u>	<u>1,428</u>	<u>3,503</u>
APPROPRIATIONS AMONG FUNDS:				
Fund balances to unrestricted (Schedule A)	126	(123)	3	—
Funds functioning as endowment to unrestricted (Schedule A)	—	—	—	—
Appropriations for buildings added to educational plant	—	(34)	(34)	—
Expendable funds used to support related expenses	—	1,002	1,002	(479)
Transferred to funds functioning as endowment (Note C)	—	(25,091)	(25,091)	—
Other appropriations	(679)	(140)	(819)	164
Total appropriations among funds	<u>(553)</u>	<u>(24,386)</u>	<u>(24,939)</u>	<u>(315)</u>
NET INCREASE (DECREASE) FOR THE YEAR	<u>—</u>	<u>(23,511)</u>	<u>(23,511)</u>	<u>3,188</u>
BALANCES, END OF YEAR	<u>\$ —</u>	<u>\$ 52,055</u>	<u>\$ 52,055</u>	<u>\$ 24,587</u>
BALANCES, END OF YEAR INCLUDE:				
Fund balances	\$ —	\$ 52,055	\$ 52,055	\$ 19,052
Outstanding borrowings	—	—	—	5,535
Total	<u>\$ —</u>	<u>\$ 52,055</u>	<u>\$ 52,055</u>	<u>\$ 24,587</u>

*Reclassified for purposes of comparison.

<i>Endowment and Similar Funds</i>	<i>Educational Plant Funds</i>	<i>Life Income and Agency Funds</i>	Total 1977	Total* 1976
<u>\$241,636</u>	<u>\$202,016</u>	<u>\$ 7,361</u>	<u>\$547,978</u>	<u>\$538,451</u>
—	—	—	37,939	34,473
—	—	—	189,639	186,637
—	909	37	8,519	9,494
—	508	388	19,783	18,532
(4,908)	—	43	(4,872)	(2,610)
—	—	—	5,959	6,488
—	218	—	218	—
—	—	—	7,414	6,893
—	—	—	3,248	2,936
7,137	4,855	382	23,044	18,528
3	—	—	663	459
—	6,300	—	11,386	2,430
<u>2,232</u>	<u>12,790</u>	<u>850</u>	<u>302,940</u>	<u>284,260</u>
—	—	—	276,912	269,250
—	834	369	3,091	3,450
201	679	—	4,217	2,033
<u>201</u>	<u>1,513</u>	<u>369</u>	<u>284,220</u>	<u>274,733</u>
<u>2,031</u>	<u>11,277</u>	<u>481</u>	<u>18,720</u>	<u>9,527</u>
—	(3)	—	—	—
—	—	—	—	1,399
—	34	—	—	—
—	(522)	(1)	—	—
25,091	—	—	—	—
1,141	285	(771)	—	(1,399)
<u>26,232</u>	<u>(206)</u>	<u>(772)</u>	<u>—</u>	<u>—</u>
<u>28,263</u>	<u>11,071</u>	<u>(291)</u>	<u>18,720</u>	<u>9,527</u>
<u>\$269,899</u>	<u>\$213,087</u>	<u>\$ 7,070</u>	<u>\$566,698</u>	<u>\$547,978</u>
<u>\$269,656</u>	<u>\$181,177</u>	<u>\$ 7,070</u>	<u>\$529,010</u>	<u>\$517,458</u>
243	31,910	—	37,688	30,520
<u>\$269,899</u>	<u>\$213,087</u>	<u>\$ 7,070</u>	<u>\$566,698</u>	<u>\$547,978</u>

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
SUMMARY OF CHANGES IN INVESTED FUND BALANCES*
for the ten years ended June 30, 1977
(In thousands of dollars)

Schedule E

	<i>1977</i>	<i>1976</i>	<i>1975</i>	<i>1974</i>
Fund balances at beginning of year	\$349,643	\$344,907	\$343,964	\$342,058
Sources of funds:				
Gifts and bequests (Note A)	\$ 23,044	\$ 18,528	\$ 16,782	\$ 18,215
Investment income (Note D)	19,783	18,532	18,332	19,099
Net gain or (loss) on sales or exchanges of investments.	(4,872)	(2,610)	443	712
Royalties received net of related costs	663	459	455	953
Receipts from foundations and agencies for student aid	4,733	5,315	5,252	4,321
Appropriations from research contract allowances ..	1,648	1,830	1,465	1,426
Government construction grants	218	—	499	3,024
Government grant for student loans	1,226	1,173	975	946
Fees, services and other receipts	9,535	9,884	6,636	3,666
	\$ 55,978	\$ 53,111	\$ 50,839	\$ 52,362
Use of funds:				
Used to meet expenses of current operation:				
Endowment investment income (Note D)	\$ 10,873	\$ 10,301	\$ 10,506	9,681
Gifts, investment income and other receipts	21,293	21,503	18,602	17,357
Scholarship and fellowship awards for tuition and stipends	9,580	8,550	8,285	7,711
Additions to educational plant	1,179	3,729	5,867	10,129
Operating expenses recorded in direct expenses of the Office of Sponsored Programs	399	1,093	673	983
Other charges to funds not related to current operation	2,941	3,199	5,963	4,595
	46,265	48,375	49,896	50,456
Net increase in funds	9,713	4,736	943	1,906
Fund balances at end of year	359,356	349,643	344,907	343,964
Less gifts and other receipts available for current expenses	11,134	10,454	10,743	9,660
Total invested funds	\$348,222	\$339,189	\$334,164	\$334,304

*This schedule has not been revised to correspond to Schedules A through D-1, however, the data is comparable for the years presented.

Schedule E (Continued)

<i>1973</i>	<i>1972</i>	<i>1971</i>	<i>1970</i>	<i>1969</i>	<i>1968</i>
\$335,318	\$328,247	\$302,901	\$290,598	\$259,882	\$239,902
\$ 16,919	\$ 17,081	\$ 34,186	\$ 14,230	\$ 23,468	\$ 20,892
18,321	16,942	15,498	15,523	14,579	13,502
2,429	1,931	7,598	6,768	14,068	9,221
1,310	978	1,058	963	1,772	698
3,999	4,280	4,787	4,441	4,624	4,698
1,457	1,383	1,209	1,698	1,405	1,627
651	776	—	92	2,188	2,028
816	923	874	556	639	699
<u>3,978</u>	<u>4,137</u>	<u>4,186</u>	<u>4,789</u>	<u>4,522</u>	<u>4,262</u>
\$ 49,880	\$ 48,431	\$ 69,396	\$ 49,060	\$ 67,265	\$ 57,627
\$ 9,794	\$ 9,602	\$ 8,435	\$ 7,354	\$ 7,351	\$ 6,865
9,193	9,471	14,529	13,704	10,344	11,113
7,965	8,162	7,999	7,533	7,279	7,566
11,969	9,151	6,513	4,283	7,067	10,076
1,640	2,246	2,869	2,627	1,957	1,062
<u>2,579</u>	<u>2,728</u>	<u>3,705</u>	<u>1,256</u>	<u>2,551</u>	<u>965</u>
<u>43,140</u>	<u>41,360</u>	<u>44,050</u>	<u>36,757</u>	<u>36,549</u>	<u>37,647</u>
<u>6,740</u>	<u>7,071</u>	<u>25,346</u>	<u>12,303</u>	<u>30,716</u>	<u>19,980</u>
342,058	335,318	328,247	302,901	290,598	259,882
<u>8,927</u>	<u>7,680</u>	<u>6,893</u>	<u>8,900</u>	<u>7,775</u>	<u>6,441</u>
\$333,131	\$327,638	\$321,354	\$294,001	\$282,823	\$253,441

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

HIGHLIGHTS: A DECADE IN REVIEW*

(in thousands of dollars)

Schedule F

	1977	1976	1975	1974**
Total Operating Expenses	\$276,912	\$269,250	\$247,441	\$233,442
Instruction and Un-sponsored				
Research Expenses	43,311	40,112	37,591	33,711
Direct Costs of Sponsored Research	158,307	157,433	142,824	139,980
Expenses Jointly Applicable to both				
Instruction and Research	50,291	48,169	45,163	39,747
Scholarships and Fellowships	9,843	8,847	8,513	7,912
Research Revenues	\$189,639	\$186,637	\$169,757	\$162,372
Tuition and Other Related Income	37,939	34,473	29,950	27,004
Investment Income	\$ 19,783	\$ 18,532	\$ 18,332	\$ 19,099
Total Gifts, Grants and Bequests	\$ 23,044	\$ 18,528	\$ 16,782	\$ 18,215
For Endowment	7,137	5,502	3,634	3,904
For Buildings	4,855	3,196	4,703	5,553
Total Fund Balances	\$529,010	\$517,458	\$508,329	\$500,925
Endowment and Similar Funds	269,656	241,192	239,248	234,551
Current Funds	52,055	75,566	76,097	81,476
Book Value of Educational Plant	203,340	201,823	197,513	190,029
Investments, at Cost	332,706	319,878	313,624	318,321
Investments, at Market	401,096	401,006	376,061	365,631
Borrowings by M.I.T.	37,688	30,520	30,122	29,369
Undergraduate Students ***	4,422	4,358	4,048	4,018
Graduate Students ***	3,774	3,603	3,468	3,358
Library, printed volumes and microforms (thousands of volumes)	2,376	2,236	2,109	1,995
Tuition Rate (in dollars)	\$ 4,000	\$ 3,700	\$ 3,350	\$ 3,100

* Where appropriate the data for the years 1968-1975 have been reclassified for comparison purposes.

** Draper Laboratory divested as of July 1, 1973

*** Full time enrollment

Schedule F (Continued)

<i>1973</i>	<i>1972</i>	<i>1971</i>	<i>1970</i>	<i>1969</i>	<i>1968</i>
\$279,061	\$245,127	\$223,222	\$225,169	\$224,649	\$220,646
29,449	26,976	27,918	25,134	23,665	22,289
192,849	161,630	140,386	149,292	157,339	155,967
37,745	37,835	36,751	33,917	28,368	27,387
8,108	8,344	8,074	7,582	7,363	7,566
\$219,447	\$187,715	\$163,429	\$171,294	\$176,206	\$174,408
24,571	22,512	21,548	19,036	18,109	16,038
\$ 18,321	\$ 16,942	\$ 15,498	\$ 15,523	\$ 14,579	\$ 13,502
\$ 16,919	\$ 17,081	\$ 34,186	\$ 14,230	\$ 23,468	\$ 20,892
2,127	2,680	3,863	1,853	4,595	6,619
5,450	2,415	2,514	3,918	2,540	2,641
\$488,240	\$469,050	\$452,558	\$420,305	\$403,361	\$365,330
229,327	221,827	216,364	189,901	169,854	149,623
84,693	85,341	80,505	85,352	101,568	89,567
182,063	157,651	143,120	136,926	127,521	120,197
318,513	312,288	303,287	278,454	265,469	237,188
420,104	425,402	382,539	308,091	354,155	345,474
30,782	20,720	17,408	14,501	11,699	12,024
4,105	4,054	4,058	4,002	3,907	3,822
3,328	3,250	3,296	3,395	3,274	3,344
1,879	1,733	1,566	1,437	1,305	1,221
\$ 2,900	\$ 2,650	\$ 2,500	\$ 2,150	\$ 2,150	\$ 1,900

NOTES TO FINANCIAL STATEMENTS

A. ACCOUNTING POLICIES

BASIS OF PRESENTATION

The accompanying financial statements have been prepared on the accrual basis. In order to ensure observance of limitations and restrictions placed on the use of the resources available to the Institute, the accounts of the Institute have been maintained in accordance with the principles of "fund accounting". This is the procedure by which resources for various purposes are classified for accounting and reporting purposes into funds that are in accordance with activities or objectives specified.

SPONSORED RESEARCH

Revenue associated with contracts and grants is recognized as related costs are incurred. Grants and contracts normally provide for a use allowance, in lieu of depreciation, which is reflected as unrestricted revenue. The Institute has recorded reimbursement of indirect costs relating to Government contracts and grants at the authorized billing rates for the fiscal years ended June 30, 1977, and 1976, which are subject to final negotiation after Government audit.

LAND, BUILDINGS, AND EQUIPMENT

Land, Buildings and Equipment, are shown at cost. As is customary for educational institutions, depreciation has not been recorded on buildings and equipment. When expended, costs associated with the construction of new educational facilities are shown as construction in progress until such projects are completed.

GIFTS

Gifts are recognized upon receipt. Gifts other than cash are recorded at their fair market value when such values are determinable as of the date of contribution.

VACATIONS

The Institute accrues vacation expense earned by certain research related employees. Other vacations are expensed as taken.

INTERFUND BORROWINGS

Interfund borrowings by Educational Plant Funds include short-term advances of \$509,000 as well as \$1,267,000 of borrowings from current invested funds (at 5%, 6%, and 8% interest) related to the temporary funding of certain buildings.

B. INVESTMENTS

Total market value of investments approximated \$401,096,000 and \$401,006,000 at June 30, 1977 and 1976 respectively. Such amounts include market values of certain real estate which were determined by professional appraisers. The Institute records bond interest as received and does not accrue discount. See the schedule of investments which appears on page 8 of the Treasurer's Report for further details.

C. ENDOWMENT AND SIMILAR FUNDS

During 1977, the Institute conducted a review of the source of designation of its funds in order to classify them between Funds Functioning as Endowment (Corporation designated) and Endowment (Donor designated). In previous years, funds had been classified only according to the nature of the restrictions on income. Based on the results of this review, which is substantially complete, the funds have been reclassified in the accompanying balance sheet (Schedule C) with \$101,453,000 classified as Funds Functioning as Endowment and \$134,661,000 classified as Endowment. Approximately \$8,400,000 of fund balances have not as yet been completely researched and have tentatively been classified as Endowment — Income for Restricted Purposes. Amounts for 1976 have been reclassified for purposes of comparison. The Institute has accounted for the funds and the income thereon in accordance with the restrictions designated by the donor or by the Corporation. In addition, during 1977, the Executive Committee of the Institute approved a transfer of \$25,091,000 of funds previously classified as Current Institute Restricted to Funds Functioning as Endowment. The transfer has been set forth separately in the appropriations among funds section of Schedule D-1.

D. INVESTMENT INCOME FOR DISTRIBUTION TO FUNDS

At June 30, 1977 and 1976, the Institute had reserved \$19,582,000 and \$19,394,000 (captioned "Investment Income for Distribution to Funds") representing fund income in excess of amounts distributed to funds in prior years. During 1977, \$10,000,000 of assets associated with the reserve were invested with the endowment and similar funds. As a result, \$10,000,000 of the reserve was transferred to Funds Functioning as Endowment (included in transfer described in Note C above). This reserve was increased by \$188,000 in 1977 and reduced by \$593,000 in 1976 as a result of the difference between income earned and income distributed to funds (see Schedule B).

E. STUDENT LOAN FUNDS

National Direct Student Loan Funds of \$11,213,000 and \$9,987,000 at June 30, 1977 and 1976, respectively, are ultimately refundable to the United States Government.

F. BORROWINGS — MORTGAGE BONDS AND NOTES PAYABLE

Borrowings — Mortgage Bonds and Notes Payable consist of the following at June 30, 1977 and 1976:

	1977	1976
M.I.T. Construction and Consolidation Bonds of 1968:		
Series A, 3 ½%, due 1977-2003	\$ 4,738,000	\$ 4,853,000
Series B, 3 ¾%, due 1977-2015	3,656,000	3,696,000
Series C, 3%, due 1977-2018	1,570,000	1,590,000
	<u>\$ 9,964,000</u>	<u>\$10,139,000</u>
Dining facilities bonds, 3 ½%, due 1977-1999	294,000	303,000
Mortgage notes payable, 5 ¼%, due 1977-1978	173,000	282,000
Mortgage notes payable, 5 ¼%, due 1977-1981	301,000	376,000
Residential facility lease purchase obligation (note G)	5,153,000**	5,225,000**
Mortgage notes payable, 5-6 ½%, due 1977-2003	9,800,000	9,965,000
Mortgage notes payable, 5-7%, due 1977-2006	6,225,000	—
	<u>\$31,910,000*</u>	<u>\$26,290,000*</u>
Total related to educational plant	243,000	395,000
Notes payable, 6%, due 1977-1978	—	49,000
Notes payable, non interest-bearing due 1977	—	—
	<u>\$ 243,000</u>	<u>\$ 444,000</u>
Total related to investment real estate	4,800,000	2,200,000
Notes payable to bank, 6 ¾%-7 ¼% due 1977-78 for student loans	—	1,000,000
Notes payable to Student Loan Marketing Association, 9 ¾%, due 1976	—	—
Notes payable to bank, 7 ¼%, due 1977 for Faculty and Staff Educational Loan Fund	150,000	100,000
Notes payable to U.S. Government, 6 ⅛%-8 ½%, due 1977-1991, for student loans	585,000	486,000
	<u>\$37,688,000</u>	<u>\$30,520,000</u>
Total		

*At June 30, 1977 the Institute had pledged securities with a market value of \$11,138,000, annual unrestricted operating revenue of \$2,120,000, and certain other project revenue to comply with the terms of the bond indentures.

**The Institute receives interest supplements from the Department of Housing and Urban Development with respect to these issues.

G. COMMITMENTS

1. Annual payments under a thirty-year residential facility lease purchase obligation payable to the Massachusetts Health and Educational Facilities Authority approximate \$350,000. Annual rentals for Utility Facilities, which are being leased for their estimated 25-year useful lives from the Massachusetts Health and Educational Facilities Authority, approximate \$900,000 and are being charged to plant operations as incurred.
2. The Institute is committed under real estate leases to a gross annual payment of \$1,188,000 in 1978. Certain leases expiring in 1977 are subject to renewal or may be renewed.
3. The Institute is committed under a lease for certain computer equipment to a gross annual payment of \$922,000 in fiscal 1978, 1979, and 1980 and \$692,000 in fiscal 1981. Upon its expiration in 1981, the lease is subject to renewal at a rate of \$143,000 annually.
4. The Institute is committed under several long-term noncancellable leases relating to real estate. The minimum aggregate rentals under these leases are \$182,000 in fiscal 1978, \$183,000 in fiscal 1979, \$128,000 in fiscal 1980, \$120,000 in fiscal 1981, and \$2,700,000 thereafter through fiscal 2003.

H. 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. Pension expense charged to operations was \$9,180,000 and \$9,029,000 in fiscal 1977 and 1976 respectively. As of July 1, 1976, a change in actuarial methods and assumptions resulted in an unfunded past service liability of \$1,200,000 which is being amortized over fifteen years. The retirement plans have been operated in conformity with the Employee Retirement Income Security Act of 1974 since January 1, 1976, and the plans' documents are being submitted to the Internal Revenue Service for requalification.

I. MERGER AND LIQUIDATION OF NORTHGATE COMMUNITY CORPORATION

On June 30, 1977, the Northgate Community Corporation, a separate non-profit organization affiliated with the Institute, was dissolved, and its assets (\$1,900,000), liabilities (\$1,680,000), and net fund balance (\$220,000) were merged with those of the Institute. The assets, consisting principally of real estate, have been included in deferred charges, inventories and other assets in the accompanying balance sheet. Upon the liquidation, the remaining book value of the Institute's investment in Northgate Community Corporation of \$2,667,000 carried in the Endowment Funds was charged against the net realized gain from investments account in the accompanying balance sheet.

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—Statement of Revenues and Funds Used to Meet Expenses of Current Operations for the Year Ended June 30, 1977 with Comparative Totals for 1976.

Schedule B—Investment Income for Distribution to Funds for the Year Ended June 30, 1977 with Comparative Totals for 1976.

Schedule C—Balance Sheet as of June 30, 1977 with Comparative Totals for 1976.

Schedule D—Condensed Statement of Changes in Financial Position for the Year Ended June 30, 1977 with Comparative Totals for 1976.

Schedule D-1—Statement of Changes in Financial Position for the Year Ended June 30, 1977 with Comparative Totals for 1976.

Schedule E—Summary of Changes in Invested Fund Balances for the Ten Years Ended June 30, 1977.

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 examined and reported upon the financial statements of the Institute for the year ended June 30, 1976.

In our opinion, the financial statements referred to above present fairly the financial position of Massachusetts Institute of Technology at June 30, 1977, the revenues and funds used to meet expenses of current operations and the changes in financial position for the year then ended, and the summarized changes in invested fund balances for the ten years ended June 30, 1977 in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

COOPERS & LYBRAND

Boston, Massachusetts, September 9, 1977

GLOSSARY FOR FINANCIAL STATEMENTS

Agency Funds — funds held as custodian or fiscal agent for affiliates such as alumni and student organizations.

Appropriations Among Funds — authorized transfer of resources between fund groups.

Borrowings — represent mortgage bonds and notes payable to external agencies, institutions and others.

Current Invested Funds — expendable resources which have been invested to produce income.

Current Operating Funds — uninvested resources held for meeting current restricted or unrestricted expenses.

Endowment and Similar Funds — encompasses both endowment funds and funds functioning as endowment. Endowment funds are gifts and bequests where the donor has stipulated, as a condition of the gift, that the principal is to remain inviolate in perpetuity and is to be invested for the purpose of producing present and future income. Funds functioning as endowment are gifts, bequests and other receipts which had no restrictions as to the expenditure of principal which the Institute elected to add to endowment funds.

Educational Plant Funds — funds invested (expended) and those available for investment (unexpended) in educational plant, as well as applicable mortgage bonds and notes payable.

Fund — an entity consisting of assets, liabilities and fund balance. The assets and income must be invested or spent in accordance with the designated purpose of the fund.

General Investments — assets of funds which have been pooled for investment purposes.

Life Income Funds — gifts for investment with income payable to one or more beneficiaries during their lives. Upon the termination of life interests, the principal becomes available for Institute purposes which may be designated by the donor.

Permanent Funds — funds designated by the donor or the Institute as unexpendable.

Plant Funds — see Educational Plant Funds.

Quasi Endowment Funds — see funds functioning as endowment in Endowment and Similar Funds.

Restricted — resources, the use of which have been designated (restricted) by a donor or the Institute.

Separately Invested Funds — funds held by the Institute and maintained in separate portfolios for investment purposes.

Student Loan Funds — resources loaned to students or available for such loans.

Unrestricted — resources which are available for the general purposes of the Institute, and are not restricted as to use.

Use of Facilities Allowances — represents the portion of sponsored research program revenues received in lieu of depreciation on facilities used for such programs.

University Fund Accounting

University finances, not unlike the rest of the world in which we live, have grown more complex as the organizations themselves have grown. At the same time, the demands for more and better information from both inside and outside the institutions have increased, often with differing objectives. Colleges and universities have tried to be responsive to these demands by improving financial reports, but there are two basic differences between corporate accounting and university finances which make it difficult to understand the financial statements of an educational institution.

What follows is a brief explanation of these two basic differences — the fund accounting concept and the availed of method of accounting:

- a) The concept of **fund** accounting, and the commonly used terms such as **restricted, unrestricted, general, designated, true endowment, funds functioning as endowment, and permanent funds** which all sound like very sharp and distinct categories in which funds are recorded, are often misunderstood. In addition, the use of funds can differ substantially from the narrow definition implied by the name given to a particular category. For example, a **restricted** fund may be drawn upon to support an activity which had been budgeted for **unrestricted** support in the Institute's annual budget process if the activity being supported qualifies under the restriction which governs the use of that particular fund. Used in that way, a restricted fund can fulfill a need for unrestricted funds.
- b) The **availed of** method of accounting makes a distinction between the recording of new resources such as investment income or gifts at the time they are added to funds, and the subsequent use of these funds when applied to meet expenditures. The following description of fund accounting and the availed of method of accounting is taken from the 1973 M.I.T. *Report of the Treasurer*.

"M.I.T., in common with other educational institutions, reports its operations and financial conditions using fund accounting, with the financial resources of the Institute called 'funds.' An accounting standards committee has defined a fund as 'a sum of money or other resources segregated for the purposes of carrying on specific activities or obtaining certain objectives in accordance with special regulations, restrictions and limitations.' Accounting for the funds of the Institute provides information on the assets, liabilities, revenues and expenses of each fund and defined group of funds, and for the funds of the Institute in total. The fund itself, however, in all of its parts including income and principal, remains a definite unit with its use for designated objectives or general Institute purposes.

"Unrestricted funds are resources received by M.I.T. for its general purposes but are not restricted as to their use. By action of the President and Executive Committee of the Corporation, they can be applied to support operating expenses, student aid, plant construction, or to the creation of endowment. Restricted resources are contributed by donors or provided by outside sponsors for defined purposes such as scholarships, professorships, plant construction, or for specific research or educational programs.

"The flow of revenues and funds reflects the 'availed of' method of accounting. Funds accumulated from prior years as well as revenues or funds received within a fiscal year may be used for operations in that year, or set aside as endowment or for other purposes in that year, or deferred for some operating or other use in a subsequent fiscal period. Tuition revenues, net research revenues, and most of the income from investments are used within the year received, but gifts, grants, bequests and other receipts of a given year are often expended later. Current expendable restricted gifts or grants are frequently received in one year but expended over more than one fiscal period, and only the amount 'availed of' in any given year is reported as revenue."

Secretary of the Institute

The Secretary of the Institute is responsible for the provision of support services to the Corporation, its officers, and committees. This report summarizes the work of the Institute's governing body under the chairmanship of Dr. Howard W. Johnson.

CORPORATION MEMBERSHIP

At the year's end the record total of 94 members of the Corporation included 76 active members, 17 life members emeriti, and 1 member-elect due to assume office at the October 7, 1977 annual meeting of the Corporation. There were 24 individuals whose membership status changed during 1976-77 in an unusually active year for the Membership Committee.

At its June 6, 1977 meeting, the Corporation elected the following four members to life membership effective July 1, 1977: Breene M. Kerr '51, Chairman and Chief Executive Officer, H-K Corporation; Frank R. Milliken '34, President, Kennecott Copper Corporation; Clint W. Murchison, Jr. '47, Partner, Murchison Brothers; and Gregory Smith '30, former President and General Manager, Eastman Gelatine Company.

At its June meeting the Corporation further elected the following ten members to five-year terms, effective July 1, 1977: W. Gerald Austen '51, Chief of Surgical Services, Massachusetts General Hospital; Yaichi Ayukawa '52, Chairman, CPC International Ltd., the first Corporation member to be elected from Japan; David R. Clare '45, President, Johnson & Johnson; W. Van Alan Clark, Jr. '42, Chairman, Sippican Corporation; Henry A. Hill '42, President and Founder, Riverside Research Laboratories, Inc.; Charles G. Koch '57, Chairman, Koch Industries; Jerry McAfee '40, Chairman and Chief Executive Officer, Gulf Oil Corporation; Denman K. McNear '48, President, Southern Pacific Transportation Company; F. Richard Meyer, III '42, Consultant in corporate mergers and acquisitions; and David S. Saxon '41, President, University of California. Vincent S. Castellano '77, Functional Liaison, Federal Reserve Bank of New York, was elected a member at the same meeting to a five-year term, effective October 7, 1977.

In addition, our Corporation member, Norman B. Leventhal '38, President, The Beacon Companies, assumed an additional ex-officio position in the Corporation by virtue of his election as the 1977-78 President of the Alumni Association. In that position, he succeeded Edward O. Vetter, effective July 1, 1977.

Two life members transferred to emeritus status at the conclusion of the year -- George J. Leness '26, former Chairman and Chief Executive Officer of Merrill Lynch, Pierce, Fenner and Smith, with 21 years of service, and David A. Shepard '26, former Executive Vice President and Director of Exxon Corporation, with 26 years of service. Both of these retiring life members have served in several Visiting Committees and all of the Standing Committees of the Corporation. Mr. Leness served a total of 16 years on the Investment Committee, and Mr. Shepard served 16 years on the Executive Committee. Both are continuing their service on Visiting Committees.

Expiration of term membership has cost the Corporation the formal services of Rebecca A. Donnellan '72, Attorney-at-Law, Fried, Frank, Harris, Shriver & Kampleman; W.H. Krome George '40, Chairman and Chief Executive Officer, Aluminum Company of America; Paul V. Keyser '29, former Executive Vice President of Mobil Oil Corporation; I.M. Pei '40, Founder and Principal, I.M. Pei & Partners; and Paul P. Shepherd '53, Principal, Paul Shepherd and Associates. These retiring Corporation members continue their association with the Corporation in many ways as members of various Corporation and Institute committees.

Under the Bylaws of the Boston Museum of Fine Arts, the President of M.I.T. annually appoints a representative from M.I.T. to serve on the MFA Board of Trustees. During the past year the Institute's representative has been Professor Phyllis A. Wallace of the Sloan School of Management. Dr. Johnson continued his brilliant service as President of the Museum of Fine Arts.

M. I. T. LEADERSHIP CAMPAIGN

By the June meeting of the Corporation, the reported totals of gifts, grants, and pledges to the M.I.T. Leadership Campaign rose to \$130 million -- more than a tripling of the \$43 million nucleus fund originally reported at the April 22, 1975 public announcement of the \$225 million, five-year Campaign. By the June 6, 1977 meeting, the remarkable total of \$130 million -- or nearly 60 percent of the total sought -- was in hand or pledged.

The pattern of positive responses from individuals, corporations, and foundations in the second public year of the Campaign was a source of very great encouragement to the Campaign Steering Committee. With the total amount just over the midpoint of the \$225 million Campaign, at the March 4 meeting, Dr. Johnson announced that W.B. Murphy and Edward O. Vetter were elected Cochairmen of the Campaign, joining Paul F. Hellmuth and himself in that capacity for the last half of the Campaign.

Corporation members serving on the Campaign Steering Committee, in addition to Dr. James R. Killian, Jr., President Jerome B. Wiesner and Chancellor Paul E. Gray, are: Paul M. Cook '47, Luis A. Ferre '24, Robert C. Guinness '34, Cecil H. Green '23, J. Kenneth Jamieson '31, Breene M. Kerr '51, Ralph Landau '41, Carl M. Mueller '41, Clint W. Murchison, Jr. '44, W.B. Murphy, D. Reid Weedon, Jr. '41, and John J. Wilson '29. Paul V. Keyser '29 is continuing his service on the Campaign Steering Committee following his completion of seven years of membership in the Corporation.

The report by Vice President James B. Lampert, who heads the staff organization for the Campaign, is included elsewhere. At the same time, no account of trusteeship would be complete without mentioning the crucial Campaign role the Corporation has assumed as members of the Campaign Steering Committee, Corporation Development Committee, Alumni Fund Board, and as area chairmen. In addition, many members of the Corporation have headed or are heading National Sponsoring Committees for particular projects and have made historic gifts of their own. For example, Breene M. Kerr is National Chairman of the Sponsoring Committee for the Building 10 drive to renovate Huntington Hall, Room 10-250, and to create a new Alumni Center on the first and second floors of the Building 10 area of the Maclaurin Buildings under the Great Dome. Clint W. Murchison, Jr. is Chairman of the \$7 million drive for a new Athletics and Special Events Center. Richard L. Terrell is Chairman of the National Business Committee seeking major grants from US and foreign corporations. Luis A. Ferre became Chairman of the Council for the Arts at M.I.T., and Gregory Smith became Cochairman of the Arts Council's Development Committee as the Council joined in merging its efforts with the Leadership Campaign. During the year, the largest pledge to the Arts since the founding of the Institute was received. As this report is being written, funds provided by Mr. and Mrs.

U.A. Whitaker have made possible the establishment of a new College of Health Sciences, Technology and Management. The establishment of the Thomas Dudley Cabot Institute Professorship honoring our life member emeritus, Thomas D. Cabot, was made possible by the Godfrey L. Cabot Charitable Trust and contributions by members of the Cabot family, led by Louis W. Cabot. Our life member emeritus, Cecil H. Green, received the 1976 Marshall B. Dalton Award of the Corporation Development Committee for his distinguished contributions to resource development over the years. Paul P. Shepherd served as Chairman of the Alumni Fund Board in a record year for the Fund. Altogether, these leadership responsibilities and actions by the Corporation constitute an unprecedented commitment by the Institute's governing body to secure the necessary resources for M. I. T.'s continued independence and strength. We are deeply grateful to the above named and to the Corporation as a whole.

MEETINGS

As a matter of record, the Corporation held four meetings during the year. For the first time since 1970, a quarterly meeting was held off campus on December 3, 1976, as the Corporation were hosts at a luncheon in New York City honoring M. I. T. alumni who currently serve as Chairmen, Vice Chairmen, or Presidents of major companies. Corporate Leadership Awards, in the form of inscribed Paul Revere Bowls, were made to 78 awardees who attended the Corporation luncheon in the Starlight Roof of the Waldorf Astoria Hotel. Some 300 guests attended. Dr. Johnson presided. President Wiesner joined him in making remarks and in presenting these unprecedented awards. Two awardees, George P. Shultz, President of Bechtel Corporation, and Carl M. Mueller, President of Loeb Roades and Co., were the principal speakers. Subsequent luncheons were held by the senior officers of the Institute in Boston and Los Angeles to complete the presentation of Corporate Leadership Awards to a total of 162 awardees. The enthusiastic reception given to this extraordinary action by the Corporation in honoring individuals for their distinguished leadership of corporate enterprise has led to the further consideration of repeating these awards in the future.

At a time of continued financial stringency, Chairman Johnson, President Wiesner, and Chancellor Gray called upon all segments of the Institute community to continue the budget reductions needed to pull together in planning for a future balanced budget. In addition, through its various committees the Corporation played a key role in communicating with students, faculty, alumni, and the general public on the range of questions and issues before M. I. T.

Special thanks are due once again to the Ad Hoc Committee on Shareholder Responsibility, under the chairmanship of George W. Thorn, and to the Corporation Joint Advisory Committee, under the chairmanship of Gregory Smith, for their continuing assistance to the Executive Committee and to the Corporation respectively. Walter L. Milne, Assistant to the President and the Chairman of the Corporation, served again as Secretary to the Committee on Shareholder Responsibility.

Additional thanks are due the Corporation Screening Committee, under the chairmanship of Rebecca A. Donnellan, and the staff of the Alumni Association for the effort required to conduct the special alumni election needed to fill a vacancy in the membership category. Representatives from Recent Classes. Under the leadership of Laurence Storch, the Corporation voted to amend the Bylaws on June 6, 1977 to simplify the nomination of Corporation members under this category of membership; the term Representatives from Recent Classes was eliminated.

In notable actions the Corporation approved the recommendation of the faculty for the substitution of S.M. degrees in Architecture for 39 B. Arch. degrees previously awarded to former graduate students in the Department of Architecture. The Corporation also approved the recommendation of the faculty to establish new Sc.D. and Ph.D. degrees in Medical Engineering and in Medical Physics under the Joint Harvard-M. I. T. Division of Health Sciences and Technology. This

latter action is of historical significance since it marks the first time that a degree program was authorized in an academic unit which is not a traditional department or school at M. I. T. The Corporation further voted to approve the elimination of certain obsolete graduate degrees not awarded since 1973 by the Department of Ocean Engineering. The establishment of the Corporate Leadership Award on December 3, 1976 has already been noted.

Two additional actions relating to faculty research were noteworthy: the October 1 tribute given to Dr. Har Gobind Khorana, Alfred P. Sloan Professor of Biology and Chemistry, for his leadership in research leading to the first complete synthesis of a functioning artificial gene; and the March 4 tribute given to Dr. Samuel C. C. Ting, 1976 Nobel Laureate in Physics, for his leadership in research leading to the discovery of the "J" particle. Dr. Ting was subsequently named Thomas Dudley Cabot Institute Professor at a special conference on April 5 honoring him, in which Thomas D. Cabot participated.

CORPORATION JOINT ADVISORY COMMITTEE ON INSTITUTE-WIDE AFFAIRS (C. J. A. C.)

Under the chairmanship of Gregory Smith, this Joint Advisory Committee to the Corporation completed its eighth year of operation. The Committee held about the same number of meetings as during the previous year but spent more of its time searching for appropriate agenda topics. Student groups which queried the Institute's budget and investment policies, tuition and financial aid, student governance, extracurricular activities, athletics, and the quality of life at M. I. T. represented the principal thrust of the Committee during the year. The writer wishes to acknowledge once again the valuable contribution the C. J. A. C. has made in building respect and mutual understanding within the M. I. T. community, despite the reduced level of Committee activity. Particular credit is due the chairman, Gregory Smith, for his skillful leadership. The Committee was assisted in its deliberations by the able, volunteer staff support of Patricia M. Maroni. Without her donated assistance, this office could not have provided staff support to C. J. A. C. We are indebted to her.

DEDICATIONS AND SPECIAL FUNCTIONS

The Corporation continued to carry prime responsibility for dedications of major facilities. Notable ceremonies this year included the dedication of the sculpture by the celebrated British artist, Sir Henry Moore, "Three Piece Reclining Figure, Draped," in the Killian Court on October 1, 1976 in the afternoon following the annual meeting. Drs. Wiesner and Johnson expressed appreciation to Mrs. Margaret McDermott, our life member, Paul M. Cook, and the artist for their generosity in making it possible to acquire this striking sculpture for Killian Court. President Wiesner also thanked Professor Wayne V. Andersen, retiring Chairman of the Committee on Visual Arts, for his leadership of the Committee and years of effort in bringing the Henry Moore to M. I. T. Also on October 1, 1976 a plaque memorializing the presidents of the Alumni Association was dedicated in the second floor corridor outside Huntington Hall, Room 10-250.

On October 2, 1976, Drs. Johnson and Wiesner spoke at the dedication of the renovated and enlarged M. I. T. Sailing Pavilion, which was named in honor of Walter C. Wood '17, longtime M. I. T. Sailing Master. Some 400 members of the M. I. T. Nautical Association and friends of sailing at M. I. T. gathered for this occasion, marking the completion of the project sponsored by a national committee of alumni under the chairmanship of George Warren Smith '26.

On March 4, 1977, at the Corporation luncheon, the Corporation formally observed the Institute's designation as a Sea Grant College, Dr. Johnson presiding. The luncheon speakers included The Honorable Michael S. Dukakis, Governor of the Commonwealth of Massachusetts, and Provost Walter A. Rosenblith. On that date in the afternoon, following the quarterly meeting of the Corporation, President Wiesner led a panel of distinguished speakers in McDermott Hall on "New Opportunities for Ocean Utilization" to mark the occasion. Other panelists were Dean Alfred A.H. Keil of the School of Engineering, founder of the M.I.T. Sea Grant Program and its first Director; Thomas D. Barrow, Senior Vice President, Exxon Corporation; Richard R. Baxter, Professor of Law, Harvard Law School; Robert M. White, Administrator, National Oceanic and Atmospheric Administration; and Carl I. Wunsch, Cecil and Ida Green Professor of Oceanography, Department of Earth and Planetary Sciences. Some 200 guests attended. Prior to the afternoon colloquium, a plaque commemorating M.I.T.'s designation as a Sea Grant College was unveiled in the first floor corridor of the Pratt Building, near the entrance to the Hart Nautical Museum. The action by the Secretary of Commerce, The Honorable Elliot L. Richardson, designating M.I.T. as a Sea Grant College took place in December 1976 and is so recorded on the plaque. An initial luncheon was held in the Sala de Puerto Rico on January 12, 1977, Dr. Rosenblith presiding, at which time The Honorable Edward O. Vetter, Undersecretary of Commerce, presented M.I.T. with the certificate of designation and made the principal address. The January 12 luncheon was held under the auspices of the Sea Grant Program, which is under the able leadership of Mr. Dean A. Horn, Director.

CORPORATION VISITING COMMITTEES

1976-77 was a busy and productive year for the Corporation Visiting Committees. Fourteen of the 27 Committees met during the year, with about 200 members attending the various on-campus meetings. One of the 14 Committees held an additional, special-purpose meeting in New York. Another Committee did not meet on the campus but held a special meeting in New York. These meetings involved roughly half of the total Visiting Committee membership, which was close to the targeted level of Visiting Committee activity. With the exception of two Visiting Committees, all of the meetings involved a two-year interval since their previous meeting. This was in keeping with the Corporation's 1975-76 guideline reducing the frequency of Visiting Committee meetings which tended to be held annually, except for those Committees which have special reasons to hold yearly or more frequent meetings. The new policy seems to be working satisfactorily; the number of meetings dropped from 18 to 14 in the first year of operation. However, the slowdown has resulted in a modest buildup of unsatisfied demand for meetings and scattered complaints.

The rationale for fewer meetings is sound in the light of the increased outreach activities of the Institute during the intensive period of off-campus campaigning under the current capital drive. The turnover among department heads, in recent years averaging around 20 percent, also has mitigated the demand for meetings somewhat, as Visiting Committee Chairmen have recognized the need of new Department heads for adequate time to develop their plans.

The method used to achieve the slowdown in the first year was to defer some annual meetings until the spring semester and to put others off for a whole year. One of the undesirable consequences was a lopsided calendar of only three meetings during fall term and 11 in the spring. A twelfth meeting had been scheduled for spring term but had to be postponed when attendance plans of several members shifted. The calendar for 1977-78 is decidedly more evenly balanced with seven or eight Visiting Committees already scheduled to meet in the first term. With luck, it should be possible to return to a more evenly distributed schedule of Visiting Committee meetings, which we have worked hard to maintain in earlier years.

Several features of the meetings which have proved successful in the past were continued by the Committees this year. All of the meetings, save two, included a dinner at which the Committee Members were brought together informally with members of the faculty and administration and in a few cases with students. Also, the Committees made effective use of private sessions with students on their agenda, further formalizing this additional and valuable means of gaining insight into departmental activities. A number of the Committees for larger departments included similar separate sessions with junior faculty. Discussions with departments included follow-up of previous Committee recommendations and reviews of departmental progress in recruitment of minorities and women as students and faculty members. One Visiting Committee devoted its entire agenda to the criteria which **should be** used as the basis for selecting a new department head to replace the retiring head. Almost all of the departments visited showed budget strains.

Attendance by members of the Visiting Committees has been outstanding this year. The 14 meetings had an average of 14 members per meeting. In addition, the participation in this year's series of meetings by the senior officers and deans of the Institute continued at a high level. The presence of these officers at the various meetings enhances the interchange between the Committee and the department and often provides a welcome catalytic effect which contributes to the success of the meeting. Warm thanks are due Dr. Rosenblith for his energetic participation both in the meetings and in the selection of new Committee members, and to the nearly 300 faculty members who participated in the sessions of the Visiting Committees.

Of the Committees meeting in the 1975-76 year, all but one of the Chairmen have now reported verbally to the Corporation, and all but one have submitted written reports. These reports to the Corporation are important to the successful operation of the Committees, and they provide a broadened forum in which to consider the plans and progress of each department. They are invaluable to the functioning of trusteeship at M. I. T. The Academic Council now systematically receives copies of the written reports when they are approved for distribution by the Executive Committee, and the Council also hears oral reports from the Provost and the responsible dean or vice president as Visiting Committee meetings occur.

To conclude this report on the 1976-77 year, I wish to express appreciation to several individuals who were associated with the Office of the Secretary of the Institute. I have already mentioned the volunteer work of Patricia M. Maroni for C. J. A. C. A number of undergraduate students from the service honorary society, Alpha Phi Omega, have also assisted this Office from time to time. I especially want to thank John L. Shelton, III, who has given selflessly of his time and creative energy. These acts of volunteerism on the part of full-time M. I. T. staff members and students have given this Office a timely lift and a heightened sense of determination to meet its recurring schedule of meetings and activities relating to the governance of the Institute. We are deeply grateful to them. We are still handicapped by reduced staffing of the Visiting Committee operation due to budgetary considerations. The search for volunteer assistance with Visiting Committee arrangements continues in order to help fill a staff vacancy.

Finally, in this period of reduced support services throughout M. I. T., I wish to thank Julie C. Reedy of the M. I. T. Alumni Association for her exceptional support of the nomination of alumni to the Visiting Committees, and for her assistance to the Corporation Screening Committee for younger alumni. The smooth operation of the special election of younger alumni as nominees to the Corporation has been due in no small measure to her dedicated service and cheerful helpfulness at all times. She will be sorely missed.

Under the category of marathon service, John J. Wilson set a record for hand signing M. I. T. degrees in the June group of degrees awarded by the Institute. In the 17 years he has hand signed degrees, Mr. Wilson has signed more than 35,000 -- this year surpassing his predecessor, the late Walter Humphreys. Messrs. Humphreys and Wilson have each signed 35,000 degrees, Mr. Wilson slightly more. Their combined total amounts to 70,000 of the 85,000 degrees awarded since the founding of the Institute.

V. A. FULMER

Alumni Association

The 1976-77 year was one of further development for the Association. It was marked by new dollar achievements in the Alumni Fund, a substantially revised alumni section of the Technology Review, and an increased level of participation in alumni programs. Also particularly noteworthy during the past year was the planning and the beginning of funding and construction of the new Alumni Center to be located in Building 10. The new Center will provide a base for alumni activities, new opportunities for alumni to interact with students and faculty, a gallery for exhibits about M. I. T. for visiting alumni and friends, and new offices for the Association staff. As part of this project, the Association also assumed responsibility for funding the renewal of 10-250, the Institute's best-known lecture hall, as a gift to M. I. T.'s students and faculty.

As a new planning process, the Association set forth in June 1976 its goals for the past year. These goals included strengthening alumni activities regionally with the staff support of the Association's new regional organization, building the performance of the Alumni Fund consistent with the goals of the M. I. T. Leadership Campaign, improvements and further development within Technology Review, and building a new set of special activities both on and off campus. In the sections to follow, progress toward these goals is reported.

Within the above goals was the intent to strengthen the Association's volunteer leadership, and under the stewardship of Edward O. Vetter, Class of 1942, as President of the Association, the Association's Board of Directors assumed an active role in the long-term planning of the Association. Mr. Vetter, while playing a national leadership role as Under Secretary of Commerce for the United States, brought to the Association a new awareness of the need for long-term planning and of the explicit setting of goals and strategies. His enthusiasm and articulate statements of the Association's and M. I. T.'s objectives were carried to M. I. T. audiences around the world. He provided exemplary service as a volunteer in the service of the Institute. He is succeeded in the Presidency of the Association by Norman B. Leventhal, Class of 1938. Mr. Leventhal currently serves as a member of the M. I. T. Corporation, and in private business is the President of the Beacon Companies of Boston. His past service in many M. I. T. activities brings a high level of experience and enthusiasm to his role as the Association's President.

During 1976-77 several members of the Association also retired or moved to other positions. Noted below are the leaving of Frederick G. Lehmann, Class of 1951, Dennis Meredith, and Katherine A. Potter. In addition to these staff members, G. Peter Grant, Class of 1935, retired from the position of Special Assistant to the Executive Vice President. Prior to serving in this last position, Mr. Grant had been Director of the Clubs of the Association for nine years. As an alumnus, friend, and staff member he served the Association and M. I. T. well. Joseph A. Edwards, Class of 1972, left the Association as Regional Director for the Southeast to assume the position of Director of the Educational Council in the M. I. T. Admissions Office. Daniel J. Fingerman, Class of 1969, left the Association in pursuit of an advanced degree in education.

Joining the Association staff and bringing renewed energies and enthusiasm were Martha S. Draper as Regional Director for the Southeast, Joseph S. Collins as Regional Director of the Mid-West, Nancy C. Pokross as Graphic Designer, and Nancy L. Russell as Assistant to the Director for Alumni Services.

ALUMNI RELATIONS

The 1976-77 alumni relations programs were the best attended and most varied in the recent history of the Association. The increased alumni interest appears to be due to the organizational changes implemented during the prior year, particularly the work of regional directors with total responsibility for alumni activities within a specific area, and the related support adjustments necessary to accomplish these changes.

The National Boards and Committees of the Association continued to review their roles particularly as they related to the planning cycle of the Association. The Technology Day Committee had earlier but less frequent meetings. This allowed sufficient lead-time to promote the annual event, particularly to reunion classes. The Alumni Council Program and Membership Committee completed a study of the Council's role recommending amendments to the Constitution which aim at building a stronger membership and reflecting changes in the Council's purpose and objectives. The amendments were approved by national ballot in the spring. It is envisioned that the Council will serve the Institute leadership as an informed forum, representative of the outside community, on long-range issues. The Club Advisory Board reduced the number of their meetings and at the same time assisted in the preparation and introduction of a club officers manual, an annual alumni attitude survey, and club evaluation procedures. This Board also recommended to the Board of Directors that the Association consider providing additional staff resources to support a higher level of M. I. T. media coverage at the local level.

The National Selection Committee and the Committee on Nominations for Corporation Visiting Committees meet only once each year. In both cases the process was timely and effective due in large measure to the efforts of the chairmen combined with efficient staff support.

The Alumni Officers Conference Committee, in addition to planning the October 1977 Conference, introduced the Robert Hallowell Richards Alumni Lecture. Named in honor of the founder of the Alumni Association and a member of the first class to graduate from M. I. T., the Lecture is to be given annually by a prominent member of the M. I. T. community and is intended to highlight the obligation alumni have to influence public policy. The Ad Hoc Committee to Strengthen Alumni Involvement with the Institute continued to meet in two groups, one involving Course (or School) liaison officers and the other involving programs with students and faculty in alumni activities not directly related to departmental ties. The Committee has begun to achieve success in several of its programs, most notably the Alumni Host Family Program for Students.

The coordination between these Committees and the Board of Directors was effective and timely. The Board continued to review its role, also recommending amendments to the Constitution designed to improve its effectiveness. These amendments were approved by national ballot and involved adding the president-elect and three members at large to the board and establishing an Executive Committee made up of the president, the immediate past president, the four vice presidents and the executive vice president ex-officio to replace the Finance Committee as well as to represent the board on a more frequent basis.

The following is a table of attendance at events over the past years:

Alumni Association

<u>Event</u>	<u>1976-77</u>	<u>1975-76</u>	<u>1974-75</u>	<u>1973-74</u>
Technology Day and Reunions	2,801	2,344	1,968	2,132
Alumni Officers Conference	571	590	745	525
Alumni Council	492	806	802	589
Club Programs	13,500	10,765	9,800	7,400
Conferences and Seminars	900	1,359	700	1,400
Summer Colleges	<u>212</u>	<u>--</u>	<u>--</u>	<u>--</u>
TOTAL	18,476	15,864	14,015	12,046

The increase in club programs and attendance over prior years is undoubtedly attributable to the organizational changes previously mentioned. Major conferences were de-emphasized as they did not appear to be as effective as other programs except for special cases. Staff support was redirected to support two summer colleges in July -- one in Cambridge and the other in Aspen, Colorado.

There were 215 club programs held during the year. Highlights included the 29th Mexico Fiesta, for the first time held in the Yucatan (160 attendees). Professor Harold E. "Doc" Edgerton and his colleagues proved to be a big attraction, speaking at nine clubs including Boston, New York, Washington, DC (2 sessions), Toronto, and Denver (total audience, 2,286). The M.I.T. Shakespeare Ensemble performed for the Boston Stein Club, Hartford, Philadelphia/Wilmington, Northern New Jersey, and Baltimore (total audience of 635). The M.I.T. Club of Cape Cod concluded its first year as a club with a successful dinner at which Professor Robert Mann spoke on "Technology and Human Rehabilitation" (150 attendees). Warren Seamans, Director of the M.I.T. Historical Collections, visited six clubs in Florida (Orlando, Jacksonville, Miami, Palm Beach, Sarasota, and Tampa) showing a film on M.I.T. and its activities up to 1950. The Boston Club had a successful year and branched out with two suburban groups, Route 128 as a luncheon club and the North Shore Suburban Club holding two well-attended events. The M.I.T. Club of Southern California and the M.I.T. Council for the Arts sponsored the "World of Franklin and Jefferson" in Los Angeles (350 attendees). In conjunction with the clubs, M.I.T. sponsored three major events and conferences: The Second Florida Festival (300 attendees), Energy Symposium and Annual Dinner Meeting, Los Angeles (200 attendees), and New York Seminar on Innovation (400 attendees).

The 1976 Alumni Officers Conference held on September 17 and 18, 1976, was attended by 421 alumni and 50 guests. The afternoon of the 17th included a new series of workshops for all officers -- Fund, Educational Council, Club, Class, Course -- and informal lunches with students, which were well attended. Ten Bronze Beaver and five Presidential Citations were given to alumni and organizations in recognition of distinguished service to the Institute through Association programs.

The 1977 Technology Day and the Class/Course reunions also had record attendance -- 2,801 alumni and guests visited M.I.T. over a four-day period from June 9 to 12, 1977 (a 19 percent increase over last year). All of the quinquennial classes held their reunions on campus, only two having a portion off campus. A total of 779 alumni, 598 guests, and 200 children attended these reunions. Twelve departments held functions for alumni during the weekend, ranging from informal receptions to formal banquets. The increase in attendance at these events developed from modest efforts over the past few years to build departmental ties.

The success of Technology Day can probably best be measured by the attendance at the lectures and at lunch on Friday. This year's program emphasized new frontiers of knowledge being explored by younger faculty. The program was held during both the morning and afternoon in Kresge Auditorium, and for the first time since 1972 the auditorium was full at both sessions. The Friday luncheon was attended by 1,461 alumni and guests, an increase of 16.5 percent over last year.

Nominations and Elections

The National Selection Committee met on November 30, 1976, to select the Association's Corporation nominees and national officers as follows: for five-year terms on the Corporation, Yaichi Ayukawa, Class of 1952; F. Richard Meyer, Class of 1942; and Denman K. McNear, Class of 1948; for a one-year term as President of the Association, Norman B. Leventhal, Class of 1938; for two-year terms as Association Vice Presidents, Franklin M. Jarman, Class of 1953 and Joe F. Moore, Class of 1952; for two-year terms as Association Directors, District 3, Ward J. Haas, Class of 1943; District 6, Robert W. Wright, Jr., Class of 1950; District 7, Russell L. Law, Jr., Class of 1948; District 8, Edward Hanley, Class of 1948; and District 9, Harold H. Strauss, Class of 1938.

A ballot was sent to all alumni in April containing the amendments to the Constitution previously mentioned, as well as the names of nine alumni nominated by their clubs to serve three-year terms on the National Selection Committee. Robert M. Dawson, Class of 1955, Hartford, Connecticut; Edward Hanley, Class of 1948, Denver, Colorado; and Christian J. Matthew, Class of 1943, San Rafael, California, were elected to serve on the Committee.

The response to the ballot this year was 4.2 percent, up from 1 percent a year ago and approximately the same as recent prior years.

The Association also supports the election process for Corporation Representatives from Recent Classes. Vincent Castellano, Class of 1977, was nominated from a slate of seven candidates to serve a five-year term on the Corporation. The ballot response this year was 8.8 percent, the highest since 1973.

A total of 69 alumni were nominated by the Association's Committee on Nominations for Corporation Visiting Committees to fill vacancies on the Visiting Committees, and 25 alumni were appointed by the Board of Directors to fill vacancies on the Association's six national committees.

Alumni Records and Data Processing

As of June 30, 1977, the rolls of living alumni included 66,642 names, resulting from the addition of 103 from the Class of 1976 and 1,358 from the Class of 1977, and the removal of 438 alumni reported deceased during academic year 1976-77.

At the start of the year a new budget system was implemented. It was designed to be compatible with the Institute system and to provide uniform management controls on the basis of manageable cost centers. Despite a high level of personnel turnover, organizational changes, and the normal operating problems to be expected with the introduction of any major new system, the process had been completely integrated into the Institute system by year end, and had fulfilled the recommendations of the internal auditors, with the exception of recommendations relating to the operations of the Technology Review. Plans are currently being formulated for developing a new accounting and control system for Technology Review to be implemented during the coming year.

A senior systems analyst replaced a data processing supervisor for the purpose of improving the Association's current data processing system and to design an up-to-date, flexible, and more cost-effective system. During the year, outdated components of the current system were eliminated and simplified, clerical support procedures were documented and improved, key-to-disc equipment replaced keypunching for data input, certain of the current reporting procedures -- particularly for the Fund -- were improved, and procedures for upgrading data acquisition and file maintenance were added. Despite the severe limitations of the existing systems, these activities resulted in significant cost improvement as well as some improvement in responsiveness. A systems evaluation was completed, and planning on a functional design for the new system was begun. It is anticipated that these designs will be completed and approved by the fall of next year in order that final designs may begin at that time. It is expected that a new system will be in place no later than early 1979.

ALUMNI FUND

1976-77 was an extraordinary year for the Alumni Fund. A total of \$4,850,955 was received from 21,125 donors. This total was up \$825,882 (21 percent) from 1975-76 and represents a record-high dollar performance for the Fund.

The Fund's performance was in excess of the 15 percent dollar increase established as a goal by the Alumni Fund Board. This performance can be attributed to several factors, in particular: the effectiveness of a growing volunteer network, the establishment of a Challenge Fund to raise the sights of alumni giving, the increased momentum of the M. I. T. Leadership Campaign in encouraging capital gifts, and the response by alumni to M. I. T. 's needs.

Most noteworthy during the past year was the establishment and success of a Challenge Fund. The Fund was established by an anonymous alumnus donor who by matching gift increases between \$25 and \$1,000 over an alumnus' 1975-76 gift, challenged alumni to increase their gift to M. I. T. In order to fund this matching, the anonymous donor established a \$500,000 pool. This pool was supplemented by a gift of \$20,000 by a second anonymous alumnus donor. The Challenge was so successful, that by spring, the M. I. T. administration agreed to add \$300,000 to the pool from a unitrust established by Arthur R. Harvey, Class of 1921. Of the \$820,000 available, \$812,000 was used. This represents gift increases of more than \$25 from over 25,000 alumni.

As compared to dollars, however, donor participation in the Fund for 1976-77 was disappointing. The number of donors decreased by 358 below 1975-76. This represented the fourth year in which donor participation failed to increase substantially. Although several factors appear to be contributing to this steady state, most weakness occurs in the number of donors from recent classes. The percent participation from these classes is dropping below that historically experienced by the Fund. Special attention will be given to this problem during the coming year.

The 25th, 40th, and 50th Reunion Classes of 1952, 1937, and 1927 reported five-year reunion gifts of \$1,305,225.52, \$467,327 and \$987,620 respectively. Several special projects of the Fund were also particularly successful. Among these were the Ellen Swallow Richards Professorship which received \$17,957 in gifts and earned an additional \$9,213 in Challenge Funds; the Independent Residence Development Fund received \$188,785 in gifts and earned an additional \$62,309 in Challenge Funds.

During the 1976-77 Fund year the Building 10 Fund was established under the chairmanship of Breene M. Kerr, Class of 1951. The Building 10 Fund will provide for the renewal of Room 10-250 as a gift of M. I. T. 's alumni to students and faculty. The Fund will further provide for a new Alumni Center to be constructed on the first floor of Building 10. At the

close of the year, more than \$700,000 had been received in gifts and pledges. The Fund has a goal of \$1,325,000 and it is the objective of the Steering Committee to complete the Fund during the 1977-78 year.

In response to an appeal by the President and Chancellor, \$127,000 was received for undergraduate scholarships; an additional \$57,484 was earned from the Challenge pool for this purpose.

Several components of the Fund continued to contribute to its success. These included volunteer efforts for the regional program with close to 200 regions now organized, a special gifts program conducted primarily in the fall of each year, Class and Course programs and telethons through which over 2,000 alumni were contacted. In April 1977, Frederick G. Lehmann, Class of 1951, left the position of Director of the Fund. Mr. Lehmann had served the Association for 19 years, first as Assistant Secretary, then as Secretary, and finally as Director of the Fund. Mr. Lehmann's contributions to the Association were extraordinary, and his services during the past three years as Director of the Fund brought the Alumni Fund to new record levels.

TECHNOLOGY REVIEW

Volume 79 of Technology Review had a two-fold goal: to maintain and increase the effectiveness of the magazine as a professional journal of new developments in technology and their implications; and to markedly increase the effectiveness of the Review in its alumni relations assignment for M.I.T. Our goal in the latter was to be increasingly responsive to findings of the alumni survey reported by the Analytical Studies and Planning Group in 1974: It was found that many alumni seemed inadequately informed about current events and programs at M.I.T., and that many identified at least as closely with their academic (departmental) experiences at the Institute as with their Classes.

Accordingly, with Volume 79 we inaugurated a new section of the Review devoted to alumni relations -- entitled MIT 77 in this volume and presumably MIT 78 in Volume 80. Using a distinctive typographic plan prepared by Nancy Pokross of Design Services, MIT 77, edited by Marjorie Lyon, incorporated Institute news, Class news as prepared by Class secretaries (supplied only to undergraduate alumni), and a new section of Course news which became the primary responsibility of Susanne Fairclough. The result was a more complete -- and vastly more visible -- report on M.I.T. events for alumni readers of Technology Review. In addition, three times during the year this material (not including the Class news) was bound separately as a self-cover periodical for the 25,000 alumni who do not receive Technology Review, as the successor to the separate "tabloid" MIT 76 of the previous year. Thus MIT 77 came to represent the entire alumni-relations-in-print program of M.I.T. -- a substantial assignment to which it must be increasingly effective in the years ahead.

Circulation

Throughout the year there was evidence of Technology Review's gradually increasing success as a professional journal. The quantity of magazines required to serve non-alumni subscribers and promotional needs grew from 19,600 in October/November to 24,750 in June -- the result of a modest increase in the response to direct mail promotions, growing newsstand sales, and what appears to be a small but significant increase in the renewal rate. Of 1,200 copies now placed on newsstands in principal cities, some 60 percent are sold each month; that is a good performance in terms of other magazine experience and it means that the newsstand distribution of the Review is wholly self-supporting.

Advertising

Advertising revenue declined slightly in Volume 79 because of the withdrawal of major advertising commitments by certain manufacturers and the lack of additional advertisers. A lack of advance in advertising revenues has been disturbing and a program to improve these revenues is being developed. As part of this program, a circulation audit by the Audit Bureau of Circulation, required for the consideration of the Review by many advertisers and their agencies, has begun.

Personnel

We have had valuable help on the management and promotional aspects of the Review from Ernest D. Frawley, General Manager of the Harvard Business Review. In particular, Mr. Frawley, who will continue to consult with us in 1977-78, devoted attention to the areas of non-alumni circulation, fulfillment, advertising, and accounting.

The flow of usable unsolicited manuscripts increased, especially in the late winter and spring when energy policy became a subject of national debate. Manuscripts on this subject appeared through every transom and under every door. There was no single article to match the popular interest of "Search for the Loch Ness Monster" in Volume 78, but on the average the timeliness and "quality" of our editorial content was high. In the features area, Robert C. Cowen, Class of 1949, the Christian Science Monitor's Science Editor, resumed his regular series in Technology Review in February; his "Science Report" was among our most popular features for several years beginning a decade ago, and we rejoice in its return.

Two personnel changes occurred during the year. In the spring, Katherine A. Potter, Circulation Manager for the Review, departed to join the Center for Advanced Engineering Study. Ms. Potter had worked on Review circulation since coming to the Institute in 1973. She served as the Review's first full-time circulation manager, and substantially advanced the process of securing non-alumni subscribers.

As work on Volume 79 concluded, Dennis L. Meredith resigned as Managing Editor to take a responsible position at the California Institute of Technology. In three years at the Review he contributed to all aspects of the magazine's editorial quality and was a constant advocate of its increasing variety and readability. These goals are essential to a magazine's service to its readers, but are too often lost by editors intent on the daily effort of working with authors to maintain accuracy and schedule. Sara Jane Neustadt, who joined the Review's Board of Editors in 1973, has succeeded Mr. Meredith as Managing Editor.

JAMES A. CHAMPY