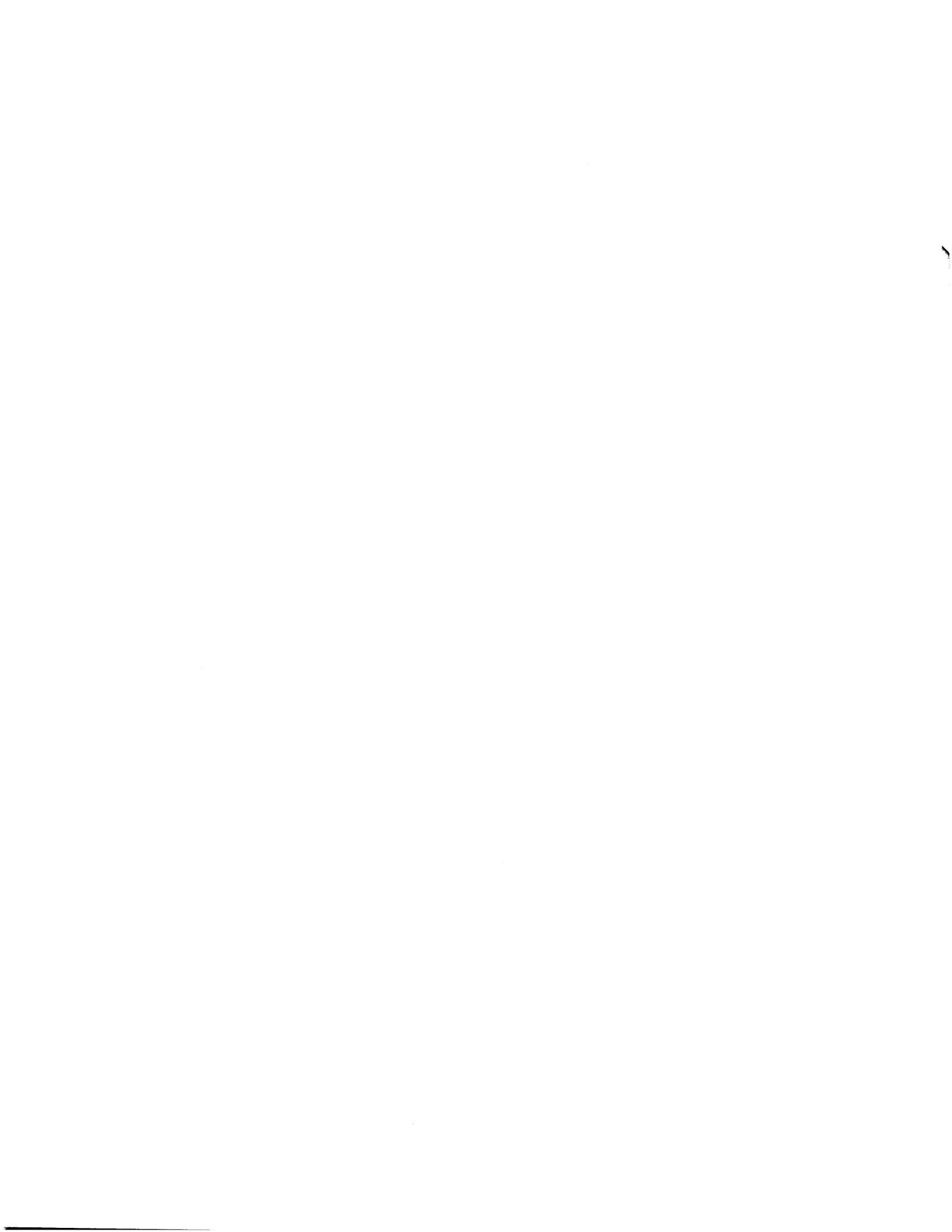


Report of the President and the Chancellor
1979-80
Massachusetts Institute of Technology

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President and Chancellor

Our report for 1980 is a challenging task, for it was a most exciting, eventful, and in many ways, difficult, year. It was, first, a time of transition for the Institute. The Chancellor was elected the fourteenth President of MIT and Francis E. Low, the Karl Taylor Compton Professor of Physics, was appointed to succeed Provost Walter A. Rosenblith as the principal academic officer of the Institute. The year also saw the highly successful completion of the Leadership Campaign and a return to the steady-state of fund-raising efforts. And it was a year when the forces of the economy and the social realm continued to exert their pressure on the university -- and on choices facing both institutions and individuals.

For President-elect Paul Gray and the new Provost, Francis Low, this is a moment of stock-taking and planning. For Walter Rosenblith and Jerome Wiesner, it is a moment for reflection as they look back on more than 30 years of involvement in the academic affairs of MIT and rejoin the ranks of the teaching faculty.

The transition to the new leadership is greatly facilitated by the continuity provided by the Chairman of the Corporation, Howard W. Johnson, and especially by the fact that for almost three years the Chancellor has been responsible for the daily management of the Institute while the President concentrated his efforts on the Leadership Campaign.

The academic programs, buoyed by the proceeds of the Leadership Campaign, continued to exhibit exhilarating vitality: the traditional disciplines evolving in search of and in response to new knowledge and new challenges, and the emerging programs continuing their development and their search for their appropriate place on the intellectual map of the Institute.

The excitement and vigor which attend this stretching of our intellectual reach is tempered, however, by the economic conditions affecting society as a whole. Even with the new support provided by the Leadership Campaign and the continued growth of the Industrial Liaison Program, MIT, like most other institutions in the society, had a hard time financially in the past year. While inflation and energy costs soared, the administration did its utmost to moderate the impact of "double-digit" inflation on all its members. Nonetheless, our faculty and staff continue to feel the decline in the purchasing power of their salaries and wages, while our students and their families dig deeper to meet the necessary, though painful, increases in tuition and other college costs. At the year's end, with the help of strenuous efforts at controlling costs and raising funds, the Institute closed its books with a small positive balance. To maintain this position in the years ahead will continue to be a challenge to the creative efforts of all -- administrators, faculty, staff, alumni, and trustees.

We have mentioned the influence of the economy on individual, as well as institutional circumstances. For undergraduate students, the pressures of the job market have led them to enroll in departments which appear to offer more immediate or practical career opportunities. Record numbers of students enrolled in many of the engineering departments and in the Sloan School of Management, creating overloads on the teaching staff and facilities which required special remedies. At the same time, other departments faced the need to accommodate, at least temporarily, smaller teaching loads.

Graduate school enrollment patterns, on the other hand, were quite different. Where problems existed, they were due in large measure to the shortage of financial support in the form of research and teaching assistantships. Parenthetically, we note with real concern the fact that the shortage in housing for graduate students has become a major problem for the Institute and its students.

Beyond the walls of the university, in a world whose momentum and values are so closely integrated with the history and future of MIT, the year just past marked the beginning of a

new decade -- one almost universally expected to be a period of diminished affluence and falling expectations. It is a decade whose outcome will, to a considerable degree, be affected by the ability to create and put to work new knowledge and new technologies, on the one hand, and by society's success in assimilating and controlling the social impact of technologies, old and new. It will also be a decade in which learning how to better manage an industrial society in an interdependent, turbulent world will be a major challenge, perhaps the dominant one. These are not new problems, but because most of the major issues confronting the world -- such as providing adequate energy and food, protecting the environment, limiting population growth, controlling nuclear weapons, bolstering industrial productivity -- tend to grow exponentially, the problems of the previous decade tend to become the crises of the next. No doubt the uniqueness of the next decade lies in the number of areas in which exponential growth makes decisive actions mandatory -- and requires new modes of thinking, new ways of managing traditional enterprises, new technologies, and wholly new disciplines. Fortunately, for MIT, the problem is not lack of ideas and possible solutions to these challenges. We must, however, continually search for the resources, the time, and the money to explore them all.

More than three decades ago, the United States emerged from World War II confident in its power, hopeful about its ability to employ technology for the common good, and optimistic about its ability to lead the world in a search for a higher standard of living and an equitable life for all. In those three decades there have been several violent swings of mood, the lows bordering on public depressions, as successes and disappointments in some major aspect of national life have captured public attention -- space exploration; medical advances; the Vietnam War; the arms race; the deteriorating environment; the emergence, and loss, of leadership in important areas; inflation; and so forth. During several of these swings, science and technology have come under attack as one of the main causes of the problem. Today, there may be some more general recognition that the provident use of new technologies is essential to the amelioration of the multi-crisis of our times. Yet, the fear of the unanticipated consequences of large-scale technologies remains.

Over the years, the MIT administration has made a special effort to understand and publicly explain the issues and to serve as a spokesman for the scientific and technical community, while attempting to enhance the related teaching and research efforts of the faculty and the student body. Much of the response by the faculty and administration to fundamental issues forged from the interaction of science, technology, and society has taken the form of developing new teaching and research activities. This is a continuing process, as vital today as at any time in the history of our nation.

In 1975, stating the goals of the Leadership Campaign, we said:

Today the Institute is unique in the extent of its teaching and research programs that encompass many areas of universal concern: energy, health care, industrial productivity, housing, the urban scene, economics, materials, communications, computers and computation, food and nutrition, education, arms control, international relations, the management of technology, natural resources, and environmental protection. These are supported by great strengths in the basic sciences, the arts, the humanities, and also by an orientation that addresses the pervasive international aspects of all these areas of study, many of which until recently could be thought of as purely domestic. Together these studies provide unique leverage on some special contemporary issues: assessing the impact of technology, improving the skill with which social and industrial organizations are managed, enhancing international security and cooperation, increasing the efficiency with which scarce resources are used, bringing artistic and human understanding into a more productive relationship with science and engineering, ensuring freedom and privacy and opportunities for all -- enhancing in all ways the roles and lives of all people in technologically based societies.

Taken as a whole, these strengths especially qualify MIT to address the sociotechnological dilemmas now confronting the nation and the world. From its students and faculty will come new resources, new technologies and techniques, new industries, new intellectual groupings, new living environments, new systems, new freedoms, and the fulfillment of important new expectations.

To scale its contributions to the needs and opportunities appropriate for today and tomorrow, the Institute has undertaken the MIT Leadership Campaign to assure an excellent faculty and outstanding students, to support significant experiments in crucial fields, and to provide a limited number of critically needed core facilities. The campaign, carefully planned to underwrite and extend the quality and strength of vital programs, is based on the belief that present world problems -- serious, complex, and even discouraging as they sometimes seem -- are in reality unprecedented opportunities for innovative individuals and institutions.

We at MIT are convinced that it is possible to expand greatly our understanding of the world and increase the wisdom and effectiveness with which we manage our affairs and use our many talents and resources. There are before us enormous opportunities to make each person's life a more rewarding experience, spiritually and culturally as well as materially, here and now, in our own time.

The fundamental purpose of that campaign to raise \$225 million in private gifts over a five-year period was to provide the resources to meet those challenges -- to undergird the financial stability of MIT in order to maintain the Institute's high quality of teaching and research, to provide the flexibility needed to explore and pioneer new fields of importance to the nation and to the world and, especially, to enhance even further the education of the superbly qualified young men and women who will play an important role in the leadership of the future. Hard work and dedication of the entire MIT family -- faculty, staff, Corporation, and administration -- made the Leadership Campaign a success. On its fifth anniversary, on April 22 of this year, the total stood at \$250,232,000, roughly 10 percent in excess of the original target. Since that date, substantial additional gifts have been recorded, and it appears that the momentum of the Campaign will result in a sustained higher level of annual giving. This effect can be seen most dramatically in this year's record Alumni Fund contributions to the Institute of \$6.3 million, a 22.5 percent gain over 1979.

The final total of \$250.2 million realized by the Leadership Campaign included \$68.1 million in new endowment, \$60.7 million for facilities, and \$121.4 million for new programs and for current use. The gifts included \$93.1 million contributed by individuals and \$80.8 million from foundations. We especially appreciate the strong support MIT received from industry in the Campaign. This special relationship with business and industry has always been a hallmark of MIT, and the \$74.7 million given by both American and foreign firms during the last five years underscores the continuing vitality of this interaction. Of the total industrial support, \$15.3 million was received for memberships in our unique Industrial Liaison and Associates programs, which have increasingly provided a powerful and productive link with industry.

Central to the Campaign was the goal of substantially increased endowment -- especially for professorships and student aid. Through the Campaign, specific gifts were made to endow 45 new professorships, including both senior professorships and the career development professorships so important to the support of younger faculty members. The new endowments, including those received after the close of the Campaign, already completed, bring to over 100 the number of endowed chairs and career development chairs now available to the Institute. In spite of this impressive progress, the number of available endowed professorships is still small relative to the quality of the MIT faculty or to the numbers of chairs at comparable institutions. We must continue to seek additional support for this purpose.

Our critical need for endowed funds for student aid also received a substantial boost during the course of the Campaign, and our initial goal has been exceeded. All told, endowment to provide future student aid has reached \$13.6 million, compared to an original objective of \$10 million. At the same time, the need in this area has grown, and we must continue to seek new endowment.

New facilities were not the dominant thrust of the Campaign, but generous support was forthcoming, nonetheless, for several key structures for which the Institute had essential and even critical need. Presently, construction is under way on major campus facilities that include the new Whitaker College of Health Sciences, Technology, and Management; the health services facility; the Athletics and Special Events Center; a new undergraduate residence on Memorial Drive; and on several vital renovation projects, including spaces to be used by the Sloan School and the Program in Science, Technology, and Society.

Throughout the Campaign, support for research and teaching programs was emphasized, and nearly half the funds raised have been provided for a multitude of current purposes in our five Schools; and in our many interdisciplinary laboratories, centers, and programs, including the Program in Science, Technology, and Society, and the Whitaker College. Of special importance is the \$17.3 million we have received in unrestricted gifts -- the kind of support that continues to be of inestimable value to the Institute in our ongoing efforts to maintain flexibility in funding new projects, while operating on a carefully controlled budget.

Needless to say, the Campaign did not end MIT's need for new resources. The specifics of the \$225 million Campaign goal represented our perception five years ago of the highest priorities among a set of needs that totaled more than \$400 million. The target represented our best judgment of an achievable effort. Since the start of 1975, inflation has added substantially to the costs of building projects and operations, and new needs in facilities and opportunities in academic programs have emerged. Consequently, even though we are pleased and gratified by the results of the Leadership Campaign, we gird ourselves for a continuing effort to seek additional resources for the Institute.

Because of the success of the Leadership Campaign, the Institute has had more of the resources, in the face of serious economic storms, needed to play its traditional role of leadership in helping to meet the nation's needs. We are pleased with the continued development of the many programs, old and new, basic and applied, undergraduate and graduate, and of the many critical new facilities that the Leadership Campaign has made possible. We draw particular satisfaction from the broadening of MIT's intellectual base in the life and health sciences, the social sciences, the arts, and the humanities.

Many of these new programs have a unique MIT personality, typically interdisciplinary, usually drawing much of their strength from links with on-going activities in engineering and science. Sometimes the influence of the older activities is direct, as in the impact of the physical sciences on the life sciences and medicine, or the influence of information-handling technology on the cognitive sciences and linguistics, and on the emerging program in media technology. Sometimes it is indirect, and is more the influence of the MIT ambience than specific interactions, as in the case of economics, psychology, and the humanities.

The past year saw attention focused on three burgeoning new activities. During the year the Department of Electrical Engineering and Computer Science committed itself to a new program in the design of large-scale integrated circuits, which hold the promise of revolutionizing much of our manufacturing activities as well as our functioning as a society in an information-rich era. This program represents a major effort by the Institute to educate more engineers expert in this important area and, at the same time, to contribute to the development of the field. It is a particularly interesting endeavor that involves the confluence of the physical sciences and the information sciences on an engineering discipline.

Integrated circuits now involve so many circuit elements and so high a degree of complexity that traditional engineering design techniques are becoming too time-consuming and costly. It is hoped that a major advance in technique can be achieved by adapting artificial intelligence techniques to the circuit design problem. But more than design advances are involved here. Most of the circuits themselves involve the need to better understand complex information processing systems: they are expected to be increasingly "intelligent" devices able to perform progressively complex tasks of computation, logic, and simulation.

The year saw, too, modest progress in the conceptualization of how MIT's manifold activities that relate to brain, behavior, cognition, neurochemistry, neuroendocrinology, perception, sensory communication and sensory defects, learning, and learning disorders can interact most effectively. The difficulty of structuring these activities should come as no surprise to anyone who has tried to reflect on or work in these areas. They span a multitude of levels of organization, from the molecular to the whole organism -- organisms whose repertory of behaviors range from the most primitive to the most humanly complex.

We want, of course, to understand how the brain develops as the organism learns and matures. We want to be able to remedy conditions, whether genetically given or environmentally induced, from birth defects to memory disorders in old age. We want to be able to take advantage of both new neuropharmacological findings and the most sophisticated computers to ensure excellent physical and mental health.

But in spite of the significant progress to which an increasing number of neuroscientists contribute in many countries, we do not understand enough to construct even an approximate theory of brain function; we do not yet know which experiments will lead to the hoped-for breakthroughs. In such circumstances, there are at the Institute several academic units and disciplines that contribute -- through instruction and research -- to the education of a new generation of brain scientists, a generation that will be in possession of more of the requisite techniques, models, and tools. In the midst of such complexity, there arise at any given time promising clusters of problems which attract clusters of colleagues from several disciplines who see an advantage in banding together in a center that will provide an intellectually more diverse environment than any single department is able to provide. Thus arose, for instance, the Center for Cognitive Science on which we reported last year. It appears that the time is now ripe for a grouping of the more biomedically oriented approaches into a Center for the Brain Sciences (or Neurosciences). Obviously the MIT Psychology Department, in the tradition of Hans-Lukas Teuber with its great strength in neuroanatomy, neurophysiology, and visual perception, is a keystone in such a grouping. But there are nearly a dozen MIT departments and laboratories in which research on the nervous system is being conducted. This obviously renders a single spatial focus impossible; however, the facilities of the Fleischmann Center for the Brain Sciences in the Whitaker College building should enable us to broaden and deepen our efforts in this area by bringing together several groups that will truly complement each other, and that will allow us to offer more powerful educational programs to MIT students.

A third major area of activity is the effort, stimulated by the MIT Council for the Arts, to provide more adequate facilities for the Institute's developing program in the arts and media technologies. This initiative has converged during the past year into a plan to bring together in a single more adequate facility the flourishing MIT exhibitions program, the creative activities in film, video and still photography, the campus-wide video production facilities, the computer music developments, the Visible Language Workshop, and the growing research and teaching activities in the area we have chosen to call media technology. By media technology we mean the emerging uses of video display and storage techniques, coupled with computer data processing and retrieval means, to facilitate human interaction with large amounts of stored information. We believe this new area holds the promise of enhancing many types of creative work (as computer-aided design has already done) by extending the reach and capabilities of the human intellect. We see, too, new publishing endeavors, involving the interaction between wideband information storage and computers. And, finally, we see in this work exciting possibilities of new learning tools and opportunities. Hardly anywhere can one find a wider spectrum of creative arts and research in related technologies than here at MIT.

In the planning process for the new arts and media technology facility, we have seen the benefits of working together across the traditional boundaries that separate these many fields. We expect that by making it possible for students and faculty in these various fields to interact more easily we will create a truly unique environment for the interaction between the arts, the humanities, and technology.

These developments are part of two major technological thrusts that offer great new societal and industrial opportunities today: the development and use of sophisticated information processing technology, and the development of the biomedical and agricultural technologies stemming from the deepening understanding of biological processes. Interestingly, these can be viewed as rather different aspects of a converging evolution of information systems, one flowing from human efforts to create systems for the processing and transmission of increasingly complex information, and the other from the study of information in living systems, including the life processes themselves.

As we look across the decades of our involvement with MIT, we can discern several basic, not unrelated, developments that have transformed the Institute. The first, of course, is the growing interaction among disciplines -- between science and engineering, and among the engineering fields -- producing new disciplines such as biophysics, biochemistry, astrophysics, computer science, biomedical engineering, and other engineering and engineering science fields. Another basic development has involved the life sciences, as the tools of physics, chemistry, and information technology are brought to bear on the mysteries and problems in the biological realm. And, as noted above, we have seen the emergence of a wholly new area of intellectual study: the information sciences are now taking their place alongside the physical and life sciences.

These developments were mentioned briefly in last year's report, but their full sweep and implications were not emphasized. It is frequently said today that the world is engaged in a second

industrial revolution, based on information technologies. In the first industrial revolution, machines came to be used to augment human and animal power in performing routine and difficult manual tasks. Similarly, it is often noted that information processing and computing systems are increasingly replacing humans in the performance of routine mental tasks. We can list many examples of this movement, ranging from the development of hand calculators, computers, and guidance systems to computer-controlled machine tools. But studies and applications of information processes extend far beyond such straightforward substitutions of machines for people.

Information systems will be able to do many things that humans cannot do. They will help reduce energy consumption by continuously optimizing energy-consuming processes. They will make it possible to better manage our complex society through the collection and processing of data on a scale heretofore impossible, through the study of the behavior of complex systems by means of computer simulation, and by the speeding up of responses and interactions.

Discoveries regarding the information flow in living systems could well have an even greater impact than machine systems, ranging from the biotechnologies beginning to be in use to major contributions to health and education. Information-related research in what we might perhaps best call the human sciences (such as human biology, the neurosciences, the cognitive sciences, and linguistics) proceeds as yet fairly independently of the machine-related work in computer and information sciences; nevertheless they enrich each other by shared understandings and research tools. The concept of coding, for example, drawn from the electrical communication field, is central to explaining certain fundamental biological processes. On the other hand, understanding the process whereby humans produce speech has made possible the computer-simulation of speech and will no doubt one day lead to practical speech recognition machines. This synergism, flowing from the simultaneous exploration of intricate living systems and increasingly complex man-made systems, has a most exciting frontier where the two paths intersect. At this junction are found, for example, the efforts to make "intelligent" prosthetic devices such as nerve-actuated artificial arms and legs, and reading and guidance devices for the blind. Here, too, are the rapidly developing efforts to exploit the power of computer and video technologies to enhance the interactions between humans and machines and thus to provide powerful new learning tools.

At MIT, the interest in information as a subject worthy of study had its origins in the computer and servomechanism work of Vannevar Bush and his colleagues, in the pioneering studies of Norbert Wiener and Arturo Rosenbluth concerning feedback in living systems, and in the early work of Claude Shannon on switching logic which later led to his by now classical theories on communication and information systems.

Many of these ideas were brought into focus by the technical developments which occurred during World War II, particularly in the field of radar, and by the concepts developed by Norbert Wiener in his enormously influential book, *Cybernetics*, which focused attention on the all-pervasive nature and fundamental importance of information to life. Wiener, along with his contemporaries von Neumann, Pitts, and McCulloch, made important advances in comparing and contrasting neurons and switches, as well as important suggestions regarding the ways in which both man-made information systems and the nervous system process signals.

Wiener's and Shannon's ideas fell on receptive and creative minds, and led in time to a broad-ranging set of research activities involving both engineers and scientists. This work was initially centered in the Research Laboratory of Electronics, and included studies of electrical signals and noise, coding systems, signal transmission in the nervous system, speech, vision and hearing, sensory prostheses, group communications, and the interaction between humans and machines. Participating in these new ventures were electrical engineers, students of brain function, psychologists, linguists, mathematicians, and people from a host of other disciplines. These early activities have long since outgrown the boundaries of RLE:

- the Departments of Psychology and of Linguistics and Philosophy have taken their place on the MIT scene;
- the computer sciences have found their own identity, and have spawned an Artificial Intelligence Laboratory very active in the area of vision;
- fundamental biology has turned increasingly to the informational aspects of life;

- work on the auditory system has given rise to the Eaton Peabody Laboratory of Auditory Physiology, a model of how new methods from communication and information technology can powerfully influence the practice of medicine;
- linguistics, experimental psychology, computer science, and artificial intelligence have come together to study cognitive processes;
- explorations of computer-aided design in the Department of Architecture have led to a sophisticated media-technology program which has far-reaching implications regarding our storage and retrieval of information;
- the study of the role of information systems in management has become embedded in the Sloan School;
- certain facets of the cognitive sciences and the use of computers as learning tools have become *foci* of much that is done in the Division for Study and Research in Education; and
- the prospects of the personal computer as an intellectual tool are now emerging.

Information science and technology, a somewhat diffuse set of activities, clearly has taken its place along with the traditional physical and life sciences and the engineering disciplines that build upon them. It is clear, too, that while much of a fundamental nature is yet to be understood regarding this somewhat mysterious commodity -- information -- its ramifications will continue to grow in societal importance. It is evident also that MIT, with its many programs in which learning about information processes plays a central role, is and will continue to be a world leader.

In Special Recognition

The honors and achievements of MIT faculty have been many this year. In this part of our report we mention some highlights of the individual efforts and awards which lend such distinction to the Institute.

This past winter, seven MIT faculty members (all of whom are alumni of the Institute) were elected to the National Academy of Engineering. The new Academy members are Eugene E. Covert, Professor of Aeronautics and Astronautics; Nicholas J. Grant, Professor of Metallurgy; Karl Uno Ingard, Professor of Aeronautics and Astronautics and of Physics; Robert C. Reid, Professor of Chemical Engineering; Herbert H. Richardson, Head of the Department of Mechanical Engineering; Gerald L. Wilson, Head of the Department of Electrical Engineering and Computer Science; and Laurence R. Young, Professor of Aeronautics and Astronautics. Their election brings to 59 the number of active and emeritus MIT faculty members in the Academy.

In April, two members of the MIT faculty were elected to the National Academy of Sciences, bringing to 78 the number of MIT officers and faculty members (active and emeriti) in the Academy. The two new members are Professor Herman Chernoff of the Department of Mathematics and Professor George W. Clark of the Department of Physics.

And in May, four MIT faculty members were elected to membership in the American Academy of Arts and Sciences. They are Rudiger Dornbusch, Professor of Economics; Jerome I. Friedman, Professor of Physics; Merton C. Flemings, Ford Professor of Engineering; and Emilio Bizzi, Eugene McDermott Professor of Brain Science and Human Behavior. Also elected to the Academy was Ralph Landau, a life member of the MIT Corporation, Chairman of the Corporation Visiting Committee for the Department of Materials Science and Engineering in 1979-80, and a member of the Visiting Committees for Chemical Engineering and Nutrition and Food Science.

Of special note this year was the selection of Institute Professor, Emeritus, Victor F. Weisskopf as a recipient of the National Medal of Science, awarded by the President to individuals "deserving of special recognition by reason of their outstanding contributions to knowledge in the physical, biological, mathematical, and engineering sciences." Professor Weisskopf was honored for his

theoretical work in quantum electrodynamics and in nuclear and particle physics. Professor Weisskopf also served as President of the American Academy of Arts and Sciences this past year.

Especially noteworthy was the selection this spring of former President and Chairman of the Corporation, Dr. James R. Killian, Jr., as the first recipient of the Vannevar Bush Award by the National Science Board, the policy-making body of the National Science Foundation. Besides serving the nation, its government, and its institutions in many ways, Dr. Killian was the nation's first full-time presidential science advisor when he served in that capacity to President Dwight D. Eisenhower. The Award was established by the National Science Board to be given in recognition of outstanding contributions to science and technology through public service. It was named in honor of the late Vannevar Bush, former professor, vice president, and dean of engineering at MIT. In 1945, Dr. Bush recommended to President Harry S. Truman that the Congress establish a foundation to support and encourage basic research and education in the sciences and to develop a national science policy. Five years later the Congress passed a bill creating the National Science Foundation to fill these roles.

In August 1979, Dr. John M. Deutch, Arthur C. Cope Professor of Chemistry, who had been on leave in various capacities in the Department of Energy, was sworn in as Undersecretary of the US Department of Energy, and served in that post until his return to the Institute in the spring of 1980. As Undersecretary, Dr. Deutch guided nuclear policy research, development of alternative energy sources, and defense and environmental programs. In March of this year he received a Tribute of Appreciation from the Department of State.

Within the Institute, special honor was given to Dr. Alexander Rich, Sedgwick Professor of Biology, who was selected as the 1980-81 recipient of the James R. Killian, Jr., Faculty Achievement Award. The Award is given each year to a member of the faculty in recognition of exceptional professional accomplishment and service to the Institute. Citing his recent discovery of a new double helical form of left-handed DNA, the award states in part: "...his research at MIT reveals a record of scientific work remarkable for its vision and quality...As a scientist with a voice in world affairs he represents the scholar who is concerned with the uses of knowledge as well as its discovery..."

Several changes in senior posts in the academic administration occurred during this past year. They include several changes in the Provost's area of responsibility. As noted above, Professor Francis E. Low was chosen to succeed Professor Walter A. Rosenblith as Provost. At the end of the academic year, Associate Provost Hartley Rogers, Jr., stepped down from that position after serving in that post for six years. Among his other duties were special responsibilities for educational video programs, the Office of Minority Education, and long-range planning for continuing education. In May, Joel Orlen, executive officer in the Office of the Provost, left the Institute to accept a vice presidency with the Minneapolis/St. Paul Museum of Science. In June, Professors Frank E. Perkins and Kenneth A. Smith were named Associate Provosts in the incoming administration. Other changes in the academic administration included the following appointments: Dr. John V. Evans, Director of the Haystack Observatory; Dr. James R. Melcher, Director of the High Voltage Research Laboratory; Dr. Merton C. Flemings, Director of the newly organized Materials Processing Center in the School of Engineering; Professors Ernest G. Cravalho and Christopher T. Walsh, Associate Directors of the recently established Whitaker College of Health Sciences, Technology, and Management. In addition, Drs. Richard L. Cartwright and Pauline R. Maier served as Acting Head and Acting Associate Head, respectively, of the Department of Humanities, until the appointment (effective July 1, 1980) of Professor Peter H. Smith as head of the Department and Associate Dean for the Humanities Programs; Dr. Abraham J. Siegel agreed to serve as Acting Dean of the Sloan School of Management, succeeding Dr. William F. Pounds, who stepped down as Dean after almost 14 years in that post in order to pursue other areas of interest; and Professor Royce N. Flippin, Jr., was appointed Director of Athletics (effective July 18, 1980), succeeding Professor Ross H. Smith, who had held that position for 19 years, prior to his retirement at the end of the 1979-80 academic year.

Several changes in senior administrative positions should also be noted. In April, Dr. Shirley M. McBay came to the Institute as Dean for Student Affairs -- following a lengthy review and re-organization of the student affairs area conducted by Vice President Constantine B. Simonides. A major outcome of that review was a renewed emphasis on support by the Dean's Office to the academic program. Prior to coming to MIT, Dr. McBay was Program Director in the Science Education Directorate of the National Science Foundation. Other changes included the appointment

of the Director of the Physical Plant, William R. Dickson, as Vice President for Operations, succeeding Philip A. Stoddard who retired at the end of the year after serving 19 years as Vice President. In March, John M. Wynne, Vice President for Administration and Personnel, left the Institute after a career of 22 years at MIT, which included his serving as Director of the Executive Development Programs and as Associate Dean of the Sloan School, prior to his appointment as Vice President in 1967. His responsibilities were assumed by Constantine B. Simonides, Vice President in the Office of the President, who now has senior responsibility in the broad area of human resources, including the various student-related services, personnel, information services, and the MIT Press.

Within the Corporation, Vincent A. Fulmer, Secretary of the Institute, was elected Secretary of the Corporation at the annual meeting in October 1979, succeeding John J. Wilson, who in his capacity as Secretary since 1959, had signed nearly 45,000 MIT degrees. Mr. Wilson, who was elected Honorary Secretary, continues as the senior active Life Member of the Corporation.

We were saddened this year by the deaths of a number of colleagues whose presence we miss, yet whose contributions to the stature and character of MIT are long-lived and gratefully remembered.

Joseph Dee Everingham, Director of Drama and Professor of Literature, died in March 1980 at the age of 63. Professor Everingham, who founded and developed MIT's undergraduate drama program, served as producer and director of many MIT Dramashop productions.

Murray F. Gardner, Professor of Electrical Engineering, Emeritus, died in August 1979. Internationally known for his work in the field of operational circuit analysis, Professor Gardner was a member of the MIT faculty for 35 years.

George Russell Harrison, Dean Emeritus of the School of Science, died in July 1979, following a long illness. An experimental physicist and spectroscopist of world renown, Professor Harrison served for 22 years as Dean of our School of Science, and set standards of excellence and achievement that have made science teaching and research at MIT preeminent throughout the world.

Harold L. Hazen, Dean Emeritus of the Graduate School, died in February 1980, at the age of 78. Dr. Hazen's seminal contributions to the field of automatic control and his dedication to research as the basis of advanced education were important building blocks in the development of MIT. During Dr. Hazen's 15-year tenure as Dean of the Graduate School, the School doubled in size and its reputation for excellence grew.

Daniel Lerner, Ford Professor of Sociology and International Communications in the Department of Political Science, died in May 1980, at the age of 62. A political sociologist, Professor Lerner was noted for his work on the role of communications in the development of third world nations.

Gilbert W. Low, Assistant Professor of Management, died in July 1979 in an automobile accident, at the age of 40. In addition to his teaching responsibilities, Professor Low was associated with the Sloan School's Systems Dynamics Group.

Theodore A. Mangelsdorf, a former member of the Corporation and a benefactor of MIT, died in August 1979, after a brief illness. An MIT alumnus, Mr. Mangelsdorf was associated with Texaco, Inc., throughout his career. Mr. Mangelsdorf served as President of the Alumni Association in 1966-67, and was the principal architect in the establishment of the New York Alumni Center.

Benjamin R. Martin, lacrosse and hockey coach for 29 years, died suddenly in January 1980, at the age of 68. One of New England's top lacrosse officials, Mr. Martin coached MIT teams from 1945 until his retirement in 1974.

Robert J. Radocchia, retired Manager of the Walker Memorial Dining Service, died suddenly in June 1980, at the age of 65. Mr. Radocchia, who had been associated with MIT for more than 40 years, was chairman of the board of the MIT Quarter Century Club. He had been singularly responsible for the development and fostering of many activities promoting a sense of community at the Institute.

Carl Richard Soderberg, Institute Professor, Emeritus, former Head of the Department of Mechanical Engineering, and former Dean of the School of Engineering, died in October 1979, at the age of 84. Dr. Soderberg was an internationally recognized engineer whose work advanced the art of

steam turbine design and hastened the development of aircraft jet engines. Considered one of MIT's most illustrious teachers, Dr. Soderberg is credited by many of his colleagues with having built the world's leading mechanical engineering department at MIT -- a department that has for years been ranked first in the nation.

Robert B. Woodward, a former member of our Corporation and professor of Chemistry at Harvard, died suddenly in July 1979. An MIT alumnus, Professor Woodward received the Nobel Prize for Chemistry in 1965. Professor Woodward served on the Corporation from 1966 to 1971.

Statistics for the Year

The following paragraphs report briefly on the various aspects of the Institute's activities and operations during 1979-80.

Registration

In 1979-80 student enrollment was 9,053, compared with 8,881 in 1978-79. This total was comprised of 4,517 undergraduates (compared with 4,594 the previous year) and 4,536 graduate students (compared with 4,287 the previous year). Graduate students who entered MIT last year held degrees from 371 colleges and universities, 232 American and 139 foreign. The international student population was 1,727, representing nine percent of the undergraduate and 29 percent of the graduate student population. These students were citizens of 96 countries.

Degrees awarded by the Institute in 1979-80 included 1,117 bachelor's degrees, 985 master's degrees, 77 engineer's degrees, 387 doctoral degrees -- a total of 2,566.

The number of women at MIT, both graduate and undergraduate, has continued to increase. In 1979-80, there were 1,565 women students (806 undergraduate and 759 graduate) at the Institute, compared with 1,466 (790 undergraduate and 676 graduate) in 1978-79. In September 1979, 207 first-year women entered MIT, representing 20 percent of the entering class.

Minority* students at MIT have increased in numbers as well. In 1979-80, there were 771 minority students (579 undergraduate and 192 graduate) at the Institute, compared with 685 (494 undergraduate and 191 graduate) in 1978-79. The first-year class entering in September 1979 included 172 minority students, representing 16 percent of the class.

Student Financial Aid

During the academic year 1979-80, the student financial aid program was again characterized by increases in overall need for financial aid, and in the aggregate amount of grants made available. There was a slight increase in the amount of MIT loans awarded, and a large increase in loans obtained from commercial sources.

A total of 2,125 undergraduates who demonstrated the need for assistance (47 percent of the enrollment) received \$7,053,446 in scholarship aid and \$2,507,679 in loans. The total, \$9,561,125, represents a six percent increase in aid compared with last year.

Scholarship assistance was provided by the scholarship endowment in the amount of \$2,527,139; by outside gifts to MIT for scholarships in the amount of \$1,504,827; and by direct grants from outside agencies to needy students totaling \$2,384,110, an increase of 44 percent from last year. Scholarship assistance from MIT's own operating funds was provided to the extent of \$511,477. The special program of scholarship aid to minority group students represented an additional \$125,893 from specially designated funds. An additional 371 students received grants from outside

* Minority students include Blacks (non-Hispanics), Native Americans (including Alaskan Natives), Hispanics, and Asian or Pacific Islanders.

Statistics for the Year

agencies. The undergraduate scholarship endowment was aided by the addition of new funds which represented an increase of about \$1,119,000 (four percent) and which raised the principal of the endowment to \$28,088,000.

Loans totaling \$2,507,679 were made to needy undergraduates -- a 13 percent increase over last year. Of this amount, \$437,711 came from the Technology Loan Fund and \$2,069,968 from the National Direct Student Loan Program. Not included in the foregoing summary is an additional \$3,534,074 obtained by undergraduates from state-administered Guaranteed Loan Programs and other outside sources. This represents an 83 percent increase in the use of these programs over last year.

Graduate students obtained \$504,636 from the Technology Loan Fund, \$197,270 of which was loaned under the Guaranteed Loan Program and qualified for Federal interest subsidies and guarantees. In addition, \$471,269 was loaned from the National Direct Student Loan Program. The total, \$975,905, represents a two percent reduction compared with last year's level. The total loaned by MIT to both graduate and undergraduate students was \$3,483,584, an increase of seven percent from last year's total -- but all of the increase was borne by the Federal National Direct Student Loan Program; loans from the Technology Loan Fund actually decreased.

Career Planning and Placement

The past year was one of continuing growth in the number of students using the Office. An estimated 1,200 students came to talk with the staff about their career plans or to meet with company and graduate school representatives. An invitation to United States students in science and engineering to submit resumés for a resumé book which the Office distributes to interested companies, elicited 747 resumés. Student interviews with visiting recruiters totaled 8,718, an all-time record. Four hundred and four companies and government agencies made one or more visits, some coming three or four times during the year.

Employer demand was strong in almost all areas of engineering and the physical sciences. It was also a good year for students in other departments who had a background in computers or economics. Management consulting firms expressed an interest in hiring analytically oriented students as research associates to work with their consulting staff for two years or so before going on to graduate school for a professional degree. Some leading banks and investment firms, and some Wall Street law firms, presented similar opportunities.

Salary offers in science and engineering rose nine to 12 percent at the bachelor's level, not quite keeping pace with inflation. Salaries at the graduate level, which in recent years have risen less fast than bachelor's salaries, this year rose equally fast or faster. Offers to master's degree candidates in electrical engineering went up 15 percent and offers to masters in materials science jumped 16 percent. Offers to Ph.D. candidates rose nine percent in electrical engineering and 11 percent in chemistry. Industrial salaries were highest for Ph.D.s in electrical engineering, hitting a median of \$31,380; next was chemical engineering, at \$29,280; followed by physics and materials science at \$28,800.

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 1978-79. Education and general expenses -- excluding the direct expenses of departmental and inter-departmental research, and the Lincoln Laboratory -- amounted to \$163,056,000 during 1979-80, compared to \$144,069,000 in 1978-79. Reflected in the finances of the Institute was the use in operations of unrestricted funds of \$5,792,000, compared with \$5,565,000 in the preceding year.

The direct expenses of campus departmental and interdepartmental sponsored research increased from \$107,521,000 to \$124,296,000; the direct expenses of the Lincoln Laboratory's sponsored research increased to \$127,347,000 from \$102,279,000 because of an overall increase in government research support.

The construction program of the Institute continued to make progress in 1979-80 with the book value of educational plant facilities increasing from \$208,195,000 to \$230,488,000.

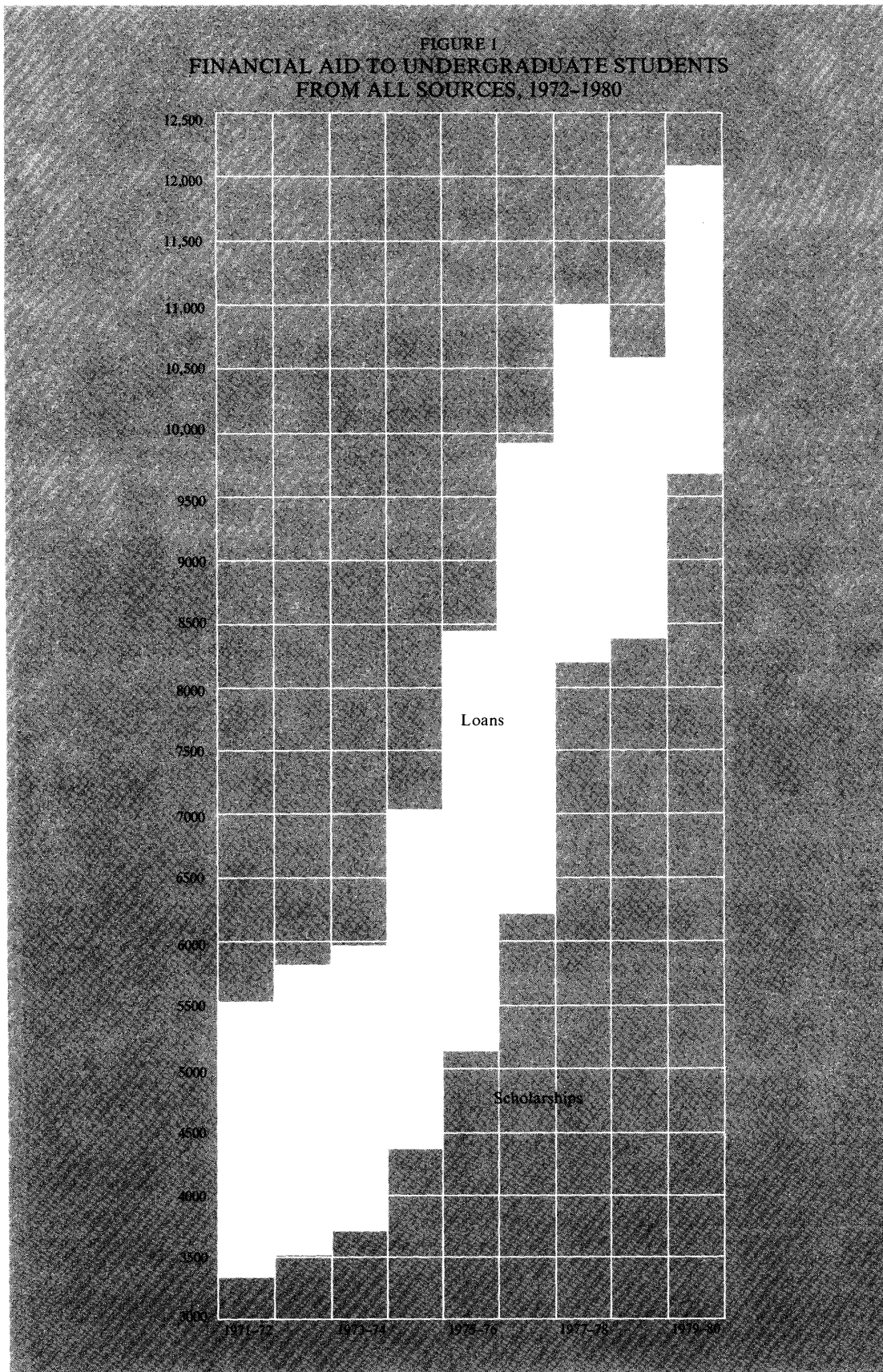


FIGURE 2
FINANCIAL AID TO GRADUATE STUDENTS
AWARDED BY MIT 1972-1980

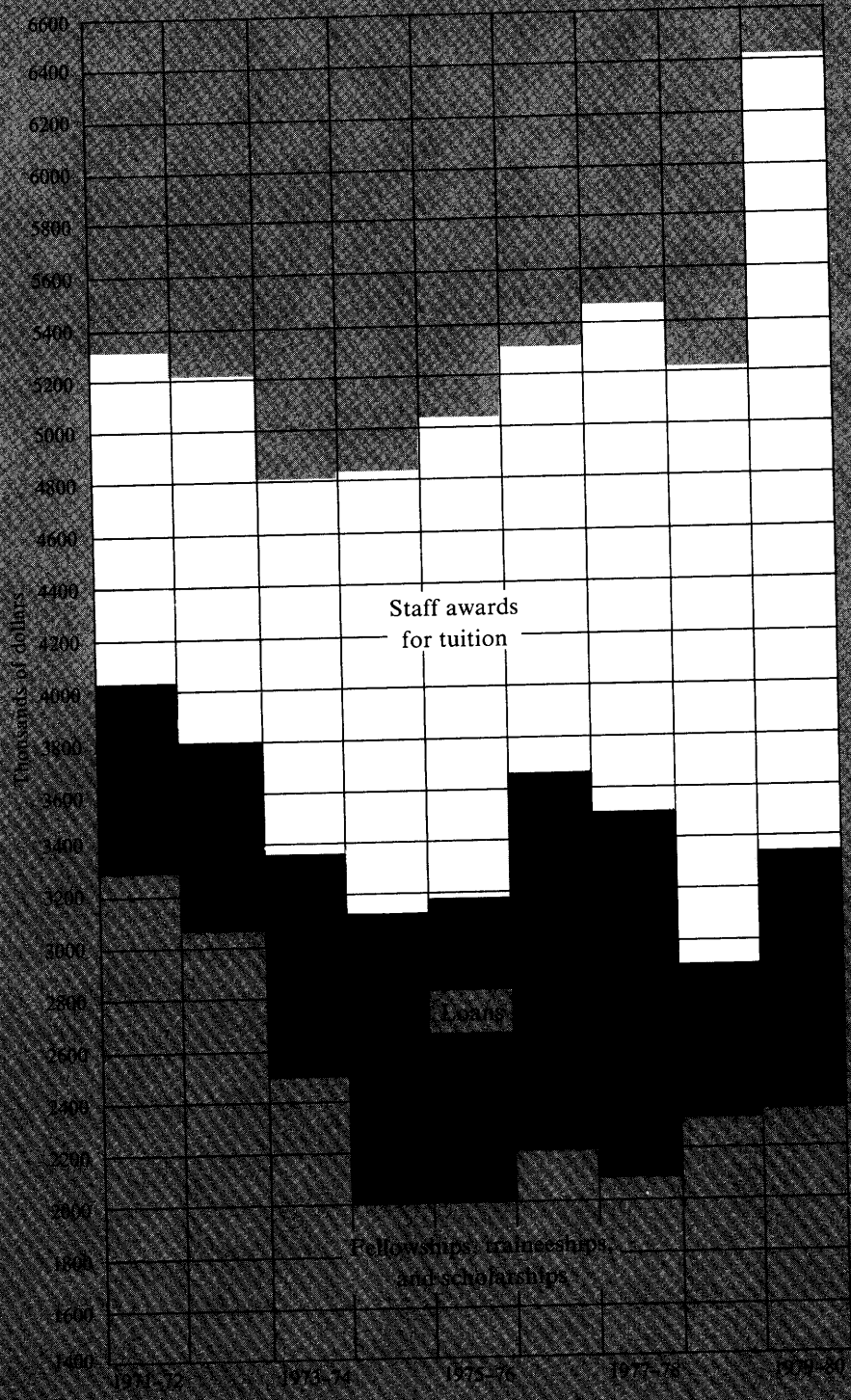
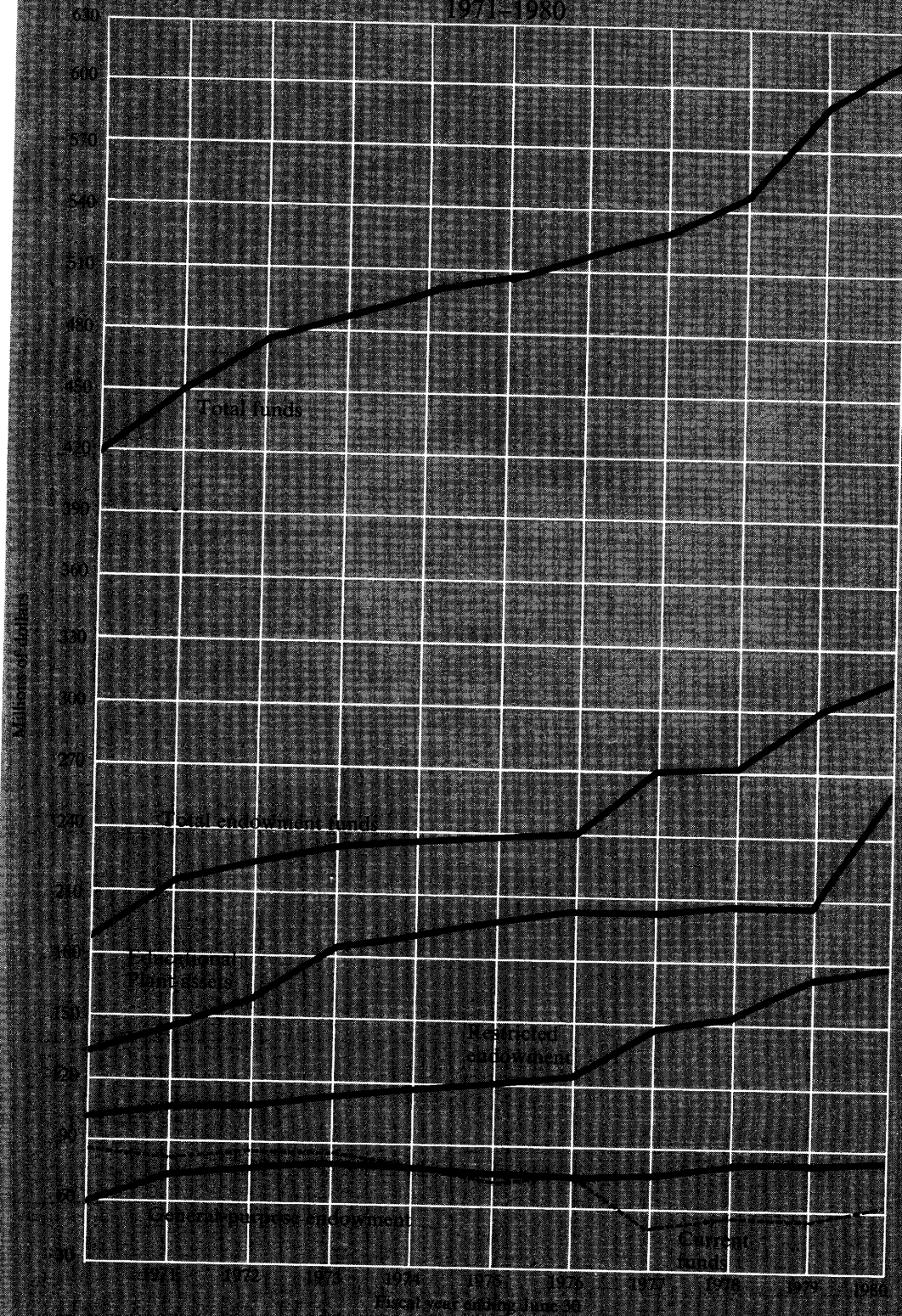


FIGURE 3
THE GROWTH OF MIT FUNDS AND PLANT ASSETS
1971-1980



Statistics for the Year

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 \$396,662,000 and a market value of \$507,471,000. This compares to book and market values of \$387,209,000 and \$467,094,000 last year.

Gifts

Gifts, grants, and bequests to MIT from private donors remained practically unchanged at \$33,841,000 in 1979-80, compared with \$33,944,000 in 1978-79. The 1979-80 figure includes unrestricted direct gifts to the Alumni Fund of \$2,700,000, which constituted part of the total of \$6,318,000 reported by the Alumni Fund in 1979-80.

Physical Plant and Campus Environment

Campus construction activity increased substantially during the year with work being initiated on three major projects: A complete renovation of the 100,000 gross square foot (gsf) former Webster Building, the new 250,000 gsf Health Sciences, Technology, and Management/Health Services complex, and a new 125,000 gsf undergraduate house located at 500 Memorial Drive. In addition, work continued on the Athletic and Special Events Center, which is scheduled to open in the fall of 1980.

In September of 1979, Kresge Auditorium was closed as a precautionary measure, five months ahead of the date previously established for a shutdown for installation of a new roofing assembly when severe deterioration of the concrete edge beams was uncovered in the vicinity of the three supporting buttresses. Alternative arrangements were made for previously scheduled events and repair work commenced immediately. Repairs to the concrete structure were completed in the spring and Kresge was scheduled to reopen in September upon completion of the originally planned roofing operation.

The report of the Committee on Campus Dining was presented to the Chancellor in the fall of 1979. The announcement of the recommendations and programs, made in the spring of 1980, recognized that the Institute has a basic responsibility to provide food services on campus at a reasonable cost to students and that dining must enhance and complement the quality of the residence program. All concerned will strive to meet the challenge set forth by these goals in the upcoming year.

JEROME B. WIESNER, President
(1971-1980)

PAUL E. GRAY, Chancellor
(1971-1980)

Personnel Changes

CORPORATION

CHANGES OF APPOINTMENT

Paul E. Gray
Chancellor and
President-Elect

Vincent A. Fulmer
Secretary of the Corporation

D. Reid Weedon, Jr.
Life Member

Jerome B. Wiesner
Life Member

John J. Wilson
Honorary Secretary
of the Corporation

ELECTIONS

Claude W. Brenner
Member

Colby H. Chandler
Member

Kenneth J. Germeshausen
Member

Shirley A. Jackson
Member

Norman B. Leventhal
Member

Harold J. Muckley
Member

John S. Reed
Member

Jean Riboud
Member

William J. Weisz
Member

David R. Wilson
Member

MEMBERS EX-OFFICIO

Harl P. Aldrich, Jr.
President
Alumni Association

TERMS EXPIRED

Virgilio Barco
Member

Vernon E. Jordan, Jr.
Member

Allan J. MacEachen
Member

Mary Frances Wagley
Member

FACULTY

DEATHS

Joseph D. Everingham
Professor in Humanities

RETIREMENTS

David N. Hume
Professor in Chemistry

Philip Mandel
Professor in Ocean
Engineering

J. Edward Vivian
Professor in Chemical
Engineering

John M. Wozencraft
Professor in Electrical
Engineering and Computer
Science

RESIGNATIONS

Professors

Jagdish N. Bhagwati
Economics

Associate Professors

Tanya M. Atwater
Earth and Planetary Sciences

George W. Brandenburg
Physics

Nicholas Catsimpoolas
Nutrition and Food Science

Wilfred R. Chassey
Athletics

Kent W. Colton
Urban Studies and Planning

Susan G. Kleinmann
Physics

Raymond E. Levitt
Civil Engineering

Peter Lorange
Sloan School of Management

Eugenia K. Rivas
Meteorology and Physical
Oceanography

Gunther Werner
Mechanical Engineering

Assistant Professors

Robert M. Alloway
Sloan School of Management

John L. Bassani
Mechanical Engineering

Ralph G. Bennett
Nuclear Engineering

Personnel Changes

Michael E. Crawford
Mechanical Engineering

William T. M. Dunsmuir
Mathematics

Martin D. Farren
Humanities

Barbara Herman
Linguistics and Philosophy

Manohar U. Kalwani
Sloan School of Management

Monroe H. Little
Humanities

Douglas E. Mahone
Architecture

Adi Shamir
Mathematics

Rachel M. Strickland
Architecture

Liba Svobodova
Electrical Engineering
and Computer Science

PROMOTIONS

To Professor:

Lotte Bailyn
Sloan School of Management

Michael J. Driscoll
Nuclear Engineering

Frederick A. Frey
Earth and Planetary Sciences

Ralph A. Gakenheimer
Urban Studies and Planning

Ann M. Graybiel
Psychology

John Harbison
Humanities

Jin-Au Kong
Electrical Engineering
and Computer Science

Heather Nan Lechtman
Humanities

John S. Lewis
Earth and Planetary Sciences

David C. Marr
Psychology

Gary T. Marx
Urban Studies and Planning

Nicholas P. Negroponte
Architecture

J. Daniel Nyhart
Sloan School of Management

Amedeo R. Odoni
Aeronautics and Astronautics

Mary Lou Pardue
Biology

David E. Pritchard
Physics

Richard R. Schrock
Chemistry

Lisa A. Steiner
Biology

Jeffrey I. Steinfeld
Chemistry

John E. Van Maanen
Sloan School of Management

To Associate Professor:

Leonard M. Adelman
Mathematics

Gregory B. Baecher
Civil Engineering

Gabriel R. Bitran
Sloan School of Management

Rowland M. Cannon
Materials Science and Engineering

Sallie W. Chisholm
Civil Engineering

Philip L. Clay
Urban Studies and Planning

Isabelle de Courtivron
Humanities

William M. Deen
Chemical Engineering

Thomas W. Eagar
Materials Science and Engineering

Glenn R. Flierl
Meteorology and Physical
Oceanography

Jeffrey E. Harris
Economics

Paul Horwich
Linguistics and Philosophy

Hilary M. Irvine
Civil Engineering

David G. Jansson
Aeronautics and Astronautics

Kenneth R. Manning
Program in Science, Technology,
and Society

Eric E. Maskin
Economics

James G. Paradis
Humanities

Ruth Perry
Humanities

Frederick A. Putnam
Chemical Engineering

Frank Solomon
Biology

Noel W. Solomons
Nutrition and Food Science

Deborah A. Stone
Political Science

Peter Szolovits
Electrical Engineering
and Computer Science

Stephen J. Tapscott
Humanities

Sherry R. Turkle
Program in Science, Technology,
and Society

Alexander J. Varshavsky
Biology

Graham C. Walker
Biology

Edward L. Wright
Physics

Gregory J. Yurek
Materials Science and Engineering
Engineering

To Assistant Professor:

Joseph V. Farrell
Economics

Amy Lang
Humanities

Ira M. Gessel
Mathematics

Lynne B. Sagalyn
Urban Studies and Planning

Gunther Uhlmann
Mathematics

CHANGES OF APPOINTMENT

Samuel M. Allen
Assistant Professor in Materials
Science and Engineering

Thomas M. Antonsen, Jr.
Assistant Professor in Physics

Gregory R. Baker
Assistant Professor in Mathematics

Emilio Bizzi
Eugene McDermott Professor in
the Brain Sciences and Human
Behavior in Psychology

B. Clark Burchfiel
Professor of Geology and
Acting Head of Earth and
Planetary Sciences

Richard J. Cohen
Assistant Professor in Physics
and Hermann von Helmholtz Assistant
Professor in Harvard-MIT Division of
Health Sciences and Technology

Fernando J. Corbató
Director of Computing and
Telecommunications Resources in the
Office of the Provost and Professor of
Computer Science and Engineering in
Electrical Engineering and Computer
Sciences

Randall Davis
Esther and Harold E. Edgerton
Assistant Professor in Electrical
Engineering and Computer Science

John M. Deutch
Arthur C. Cope Professor
in Chemistry

Alan H. Epstein
Assistant Professor in
Aeronautics and Astronautics

John V. Evans
Professor in Meteorology and
Physical Oceanography, Assistant
Director of Lincoln Laboratory, and
the Director of Haystack Observatory

Jerome I. Friedman
Professor in Physics and Director of
Laboratory for Nuclear Science

Fred M. Gelbard
DuPont Assistant Professor of
Chemical Engineering in
Chemical Engineering

J. Michael Gerzo
Research Associate in
Plasma Fusion Center

Lance A. Glasser
Assistant Professor in
Electrical Engineering and
Computer Science

Paul D. Gottlieb
Visiting Scientist in Center
for Cancer Research

Howard Green
Visiting Professor in Biology

D. Edmunds Harrison
Visiting Assistant Professor
in Meteorology and Physical
Oceanography

Carolyn D. Heising-Goodman
Assistant Professor in
Nuclear Engineering

Ellen J. Henderson
Visiting Scientist in Chemistry

Robert M. Hollister
Visiting Associate Professor in
Urban Studies and Planning

Gerald Holton
James R. and Elizabeth P. Killian
1926 Visiting Professor in the
Program in Science, Technology,
and Society

Peter W. Huber
Carl Richard Soderberg Associate
Professor in Power Engineering in
Mechanical Engineering

Timothy L. Johnson
Visiting Scientist in Laboratory
for Information and Decision
Systems and Lecturer in Electrical
Engineering and Computer Science

Ralph Katz
Senior Lecturer in Sloan School
of Management

Paul R. Krugman
Ford International Associate
Professor in Sloan School
of Management and Economics

William M.C. Lam
Adjunct Professor in Architecture

Thomas H. Lee
Cecil H. Green Professor in
Electrical Engineering and
Computer Science

Richard K. Lester
Esther and Harold E. Edgerton
Assistant Professor in
Nuclear Engineering

Francis E. Low
Provost and Karl Taylor Compton
Professor in Physics

Margaret L.A. MacVicar
Associate Professor in Physics
and Cecil and Ida Green Associate
Professor of Physical Science and
Education in the Division for Study
and Research in Education

Michael A. Marletta
Assistant Professor in Nutrition
and Food Science

James W. Mar
Jerome Clarke Hunsaker Professor
of Aerospace Education in
Aeronautics and Astronautics

M. Lynne Markus
Assistant Professor in Sloan School
of Management

Robert B. McKersie
Professor in Sloan School of
Management

Robert C. Merton
J.C. Penney Professor of
Management in Sloan School
of Management

Stephen M. Meyer
Assistant Professor in Political Science

Personnel Changes

Henry A. Millon
Visiting Professor in Architecture

Hamish N. Munro
Adjunct Professor in
Nutrition and Food Science

John N. Newman
Professor and Acting Head
in Ocean Engineering

Walter H. Olson
Associate Professor in Electrical
Engineering and Computer Science
and Hermann von Helmholtz Associate
Professor in Harvard-MIT Division
of Health Sciences and Technology

Frank E. Perkins
Associate Provost and Professor
in Civil Engineering

William F. Pounds
Professor in Sloan School of
Management

Harilaos N. Psaraftis
Henry L. Doherty Assistant
Professor in Ocean Utilization
in Ocean Engineering

Daniel G. Quillen
Norbert Weiner Professor
in Mathematics

William H. Rastetter
Roger and Georges Dirmenich
Assistant Professor in Chemistry

L. Rafael Reif
Analog Devices Career
Development Assistant Professor
in Electrical Engineering and
Computer Science

Stanley R. Rich
Gordon Adjunct Professor in
Electrical Engineering and
Computer Science

Robert O. Ritchie
Class of 1922 Career
Development Associate Professor
in Mechanical Engineering

Harriet Ritvo
Assistant Professor in Humanities

Hartley Rogers, Jr.
Professor in Mathematics

Walter A. Rosenblith
Institute Professor

John Ross
Visiting Professor in Chemistry

Charles F. Sabel
Ford International Assistant
Professor of Social Science in
Program in Science, Technology,
and Society

William F. Schreiber
Gordon Professor in Electrical
Engineering and Computer Science

Irwin I. Shapiro
Schlumberger Professor of
Geophysics and Physics in Physics

Gedaliah Shelef
Visiting Professor in Civil
Engineering

Abraham J. Siegel
Acting Dean and Professor
of Industrial Relations in
Sloan School of Management

Kenneth A. Smith
Associate Provost and Joseph R.
Mares Professor of Chemical
Engineering

Ross H. Smith
Special Advisor for Athletic
Resources in the Office of
the President

Joseph M. Sussman
Department Head in Civil
Engineering

Irene Tayler
Thomas Meloy Associate
Professor in Rhetoric and
Literature in Humanities

John E. Thomas
Charles Stark Draper Assistant
Professor in Aeronautics and
Astronautics

James M. Utterback
Associate Professor in School
of Engineering

Costas G. Vayenas
Joseph R. Mares Assistant
Professor in Chemical Engineering

George M. Whitesides
Robert T. Haslam and Bradley
Dewey Professor in Chemistry

Jerome B. Wiesner
President Emeritus and
Institute Professor

Gerald N. Wogan
Department Head and Underwood-
Prescott Professor in Nutrition
and Food Science

Lothar Wolf
Visiting Associate Professor
in Mechanical Engineering

Bernhardt J. Wuensch
Acting Department Head and
Professor of Ceramics in Materials
Science and Engineering

Richard E. Zippel
Assistant Professor in Electrical
Engineering and Computer Science

Victor W. Zue
Assistant Professor in Electrical
Engineering and Computer Science

NEW FACULTY APPOINTMENTS

Professors:

Ernst R. Berndt
Sloan School of Management

Erich P. Ippen
Electrical Engineering and
Computer Science

Royce N. Flippin, Jr.
Director of Athletics and
Professor in Athletics

Daniel Z. Freedman
Mathematics

Thomas A. Kochan
Sloan School of Management

Earl M. Murman
Aeronautics and Astronautics

K. Barry Sharpless
Chemistry

Peter H. Smith
Department Head in Humanities,
Associate Dean for Humanities
Programs, Professor of History,
and Professor of Political Science

Cynthia Wolff
Humanities

President and Chancellor

Associate Professors:

John R. Hauser
Sloan School of Management

Henry G. Irwig
Civil Engineering

Wallace K. Melville
Civil Engineering

Jefferson W. Tester
Chemical Engineering

Markus Zahn
Electrical Engineering and
Computer Science

Assistant Professors:

Katharine G. Abraham
Sloan School of Management

Bernard Avishai
Humanities

Iiona Bell
Humanities

Alan Bleier
Materials Science and Engineering

William M. Bowles
Aeronautics and Astronautics

James G. Branson
Physics

Harvey J. Bryan
Architecture

Wai Kong Cheng
Mechanical Engineering

Edward F. Crawley
Aeronautics and Astronautics

David Dobrin
Humanities

Antonio L. Elias
Aeronautics and Astronautics

Jawaid A. Ghani
Sloan School of Management

Mel Horwitch
Sloan School of Management

Ravindran Kannan
Mathematics

Timothy J. Kehoe
Economics

Alexander Klibanov
Nutrition and Food Science

Jeffrey H. Lang
Electrical Engineering and
Computer Science

Dorothy A. Leonard-Barton
Sloan School of Management

Andrew B. Lippman
Architecture

Philip S. Marcus
Mathematics

Terry A. Marsh
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Alan C. Nelson
Nuclear Engineering and
Harvard-MIT Division of
Health Sciences and Technology

W. Russell Neuman
Political Science

Raymond T. Pierrehumbert
Meteorology and Physical
Oceanography

Manoj K. Prasad
Mathematics

Melinda Rabb
Humanities

Ram T. S. Ramakrishnan
Sloan School of Management

Shelley Rasmussen
Mathematics

Terry A. Ring
Materials Science and Engineering

Edward Robbins
Architecture

Julio J. Rotemberg
Sloan School of Management

Richard S. Ruback
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Raaj Sah
Urban Studies and Planning

Richard J. Samuels
Political Science

Herbert H. Sawin
Chemical Engineering

J. Mark David Schuster
Urban Studies and Planning

H. David Sherman
Sloan School of Management

Michael F. Sipser
Mathematics

Brian H. Smith
Political Science

Robert Sturges
Humanities

Robert R. Tenney
Electrical Engineering and
Computer Science

Francis T. Walsh
Athletics

Clifton L. West, III
Athletics

Gary E. Wnek
Materials Science and Engineering

JoAnne Yates
Humanities

Adjunct Professors:

Giancarlo De Carlo
Architecture

G. David Forney
Electrical Engineering and
Computer Science

VISITING FACULTY

Visiting Institute Professors:

Jean Leray
Mathematics

Visiting Professors:

Mark Azbel
Physics

David A. Belsley
Sloan School of Management

Pei-Yuan Chou
Physics

Personnel Changes

Petr Chylek Civil Engineering	Tarik Sabuncu Ocean Engineering	Reuben Gronau Economics
Giuseppe Colombo Aeronautics and Astronautics	Bal Raj Sehgal Nuclear Engineering	Alan Guth Physics
James Durbin Sloan School of Management	Richard H. Sillitoe Earth and Planetary Sciences	James T. Higginbotham Linguistics and Philosophy
Odd M. Faltinsen Ocean Engineering	Kumares C. Sinha Civil Engineering	Robert D. Hisrich Aeronautics and Astronautics
Sheldon Glashow Physics	Stanley B. Troup Sloan School of Management	Vasudev C. Joshi Chemistry
Harry G. Judge Division for Study and Research in Education	Ben-Zion Weiss Materials Science and Engineering and Materials Processing Center	Samuel A. Latt Biology
Julian Keilson Mathematics	Konrad Weller Architecture	Shlomo Libeskind Division for Study and Research in Education
Dogan Kuban Architecture	Michael Wheeler Urban Studies and Planning	Pearla Neshor Division for Study and Research in Education
Roslyn Lindheim Division for Study and Research in Education	John H. Williamson Economics	Richard A. Shore Mathematics
Otto E. Lowenstein Aeronautics and Astronautics	Tomasz Wierzbicki Ocean Engineering	Stefanie Stanzl Mechanical Engineering
S. Stanford Manson Aeronautics and Astronautics, Mechanical Engineering, and Materials Science and Engineering	William H. Wing Physics	Joel Tennenbaum Meteorology and Physical Oceanography
Mihajlo D. Mesarovic School of Engineering	Taketoshi Yamada Ocean Engineering	Moneer F. Tewfik Civil Engineering
Anil Nerode Mathematics	Pei-Yuan Zhou Physics	Elmar K. Tschegg Mechanical Engineering
Itaru Niimi Materials Science and Engineering	<u>Visiting Associate Professors:</u>	Floyd R. Tuler Materials Science and Engineering
James L. Park Nuclear Engineering	Amnon Aharony Physics	Johannes J. Van Dixhoorn Mechanical Engineering
Hugo Perez La Salvia Civil Engineering	Peter Atkinson Ocean Engineering	Francois Vannucci Physics
Walter V. Philipp Mathematics	Robert W. Burpee Meteorology and Physical Oceanography	Albert H. Walenta Physics
Noel K. Pope Nuclear Engineering	Charles H. Byers Chemical Engineering and Director, MIT Practice School Station at Oak Ridge, Tennessee	Akira Watanabe Mechanical Engineering
Thomas A. Porsching Nuclear Engineering	Paul D. Calvert Materials Science and Engineering	Yehoshua Y. Zeevi Aeronautics and Astronautics
Desari R. Rao Physics	Nicolas G. Garcia Aeronautics and Astronautics	

President and Chancellor

Visiting Assistant Professors:

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Sciences and Technology

Michael G. Akritas
Mathematics

Peter C. Cornillon
Meteorology and Physical
Oceanography

Jean-Marie Dufour
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John G. Giuliano
Linguistics and Philosophy

Jane B. Grimshaw
Linguistics and Philosophy

Christina Hooper
Architecture

Saj-nicole A. Joni
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Urban Studies and Planning

Hyde M. Merrill
Electrical Engineering and
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Takuji Murao
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John Richards
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Edwina L. Rissland
Division for Study and
Research in Education

Jean N. Spaltenstein
Mathematics

Yannis P. Tsividis
Electrical Engineering and
Computer Science

Stuart Wrede
Architecture

AWARD

David J. Rose
Professor in Nuclear Engineering;
Killian Award Lecturer for
the Academic Year 1979-80

ADMINISTRATION

RETIREMENTS

Robert V. Dodd
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John M. Wynne
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Administration and Personnel

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Personnel Changes

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Division of Comparative Medicine

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Coordinator of Dining/Research
Program
Dean for Student Affairs

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Personnel Officer
Office of Personnel Services

CHANGES

Katherine K. Allen
Administrative Assistant to
the Director
Industrial Liaison Office

Nelson Armstrong
Associate Director
Admissions

Richard S. Armstrong
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Coordinator of the Master's
Program
Sloan School of Management

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Section
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Resource Development
Vice President for Resource
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Integrated Circuit Fabrication
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Department of Electrical Engineering
and Computer Science

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Office of Sponsored Programs

President and Chancellor

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Department of Purchasing
and Stores

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Libraries

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School of Architecture
and Planning

Paula B. Cronin
Director of Placement
Sloan School of Management

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Information Processing Services,
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Office of Personnel Services

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Department of Nuclear Engineering

Cynthia K. Dick
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Department of Biology

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Gerald P. Donovan
Safety Officer
Safety Office

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Operations

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Office of Sponsored Programs

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Comptroller's Accounting Office

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Associate Director of Executive
Education Programs and Lecturer
Sloan School of Management

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Office of the Provost

Harris D. Eigabroadt
Supervisor, Video Production
and Maintenance
Office of the Provost

Mary Z. Enterline
Manager of Independent Activities
and Wellesley Exchange
Office of the Provost

Jacquelyn M. Findlay
Assistant Director of Corporate
Relations
Vice President for Resource
Development

John T. Fitch
Director, Technical Based
Education Development
Center for Advanced
Engineering Study

James T. Gabbert, Jr.
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Program in Science, Technology,
and Society

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Assistant Director
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Student Affairs
Department of Political Science

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Information Processing Services,
Operations

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Personnel Officer, Office of
the Provost
Office of Personnel Services

Jeffrey C. Harrington
Systems Programmer
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Operations

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Operations

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Staff Architect and Principal
Structural Engineer
Physical Plant

Donna P. Hawrot
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Information Processing Services,
Operations

Holliday C. Heine
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Office of the Dean for
Student Affairs

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School of Science

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Development

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Personnel Officer, Office of
the President
Office of Personnel Services

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Assistant to the Director
Office of Communications
Resource Planning

Deborah A. Hoover
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for the Arts
Office of the President

Jarmila Z. Hrbek
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to the President Emeritus
Office of the President

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Recruiting
Career Planning and Placement

Bonnie S. Jones
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Student/International Programs
Alumni Association

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Resource Planning

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Libraries

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Alumni Association

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Information Processing Services,
Operations

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Superintendent of Support
Services and Buildings
Physical Plant

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of Operations
MIT Press

Nancy K. Lombardi
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Historical Collections
Libraries

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DEATHS

Noreen J. McSorley
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School of Science

Robert J. Radocchia
Manager
Quarter Century Club

Provost

As an educational institution dedicated to the creation, dissemination, and application of scientific and technical knowledge, MIT has always been *sui generis*. Not only has it persisted in its status of being a private land grant institution, but it has throughout its history kept a steady course on the education of the young for all sectors and professions of our society that depend upon technology and science in the forging of the future.

These features emerge perhaps most clearly when visitors from foreign lands come to MIT in order to discuss with us admission of students, curricula, organizational forms, career development of the faculty, research staff and research support, the Undergraduate Research Opportunities Program (UROP), relations with industry and government as well as the administrative arrangements that are the infrastructure of these multifarious activities. Two different types of visits stand out in these past several years: 1) the flow of delegations from the People's Republic of China and 2) the senior administrators from the Swiss ETH (Eidgenössische Technische Hochschule) in Zürich.

The Chinese visitors came chiefly to learn how to rebuild their scholarly institutions which had suffered so much during the Cultural Revolution. There were many and varied delegations representing not only universities (such as Tsinghua, which at one time bore the moniker of the Chinese MIT, Chungtao University, Beijing University, etc.), the Chinese Academy of Sciences, and the newly formed Academy of Social Sciences, but also different scientific and professional organizations (in areas of Science, Engineering, Management, and Architecture). These delegations, which often had MIT alumni among their members, usually stayed only a day or two during which they tried to pack in as much information as possible, even though much of the discourse had to be translated. The leaders and members of these delegations did not expect to obtain detailed knowledge of recent progress in different disciplines but rather to gain an impression of how to build institutions that would contribute effectively to the four modernizations as formulated by Chou En-lai in 1975. They - the delegations - would also report to their colleagues and to their governmental authorities who were the most promising candidates who should apply for visiting or student status in US universities in order to acquire over a prolonged period - a year or more - the requisite knowledge to build modern institutions of higher education.

In this connection one cannot exaggerate the role that our faculty colleagues of Chinese origin have played in making these contacts fruitful; they gave generously of their time in advising delegations, in arranging meetings and social gatherings, in assisting in the evaluation of credentials of those who were going to spend significant periods at MIT, and finally in lecturing sometimes weeks and months at appropriate institutions in the PRC. But they were not the only ones to cross the Pacific in the West-East direction. A woman graduate student in MIT's Department of Earth and Planetary Sciences spent several months in the PRC working with her Chinese colleagues. Numerous other members of the MIT faculty visited the PRC either singly or as members of a group. Finally, two MIT delegations spent two to three weeks in the PRC. The first, composed of about 10 faculty members and led by Paul Gray, spent most of its stay at Tsinghua University discussing predominantly curricular issues. The second, composed of members of the Corporation, several faculty members and led by Howard Johnson and Jerome Wiesner, "toured" under the sponsorship of the Chinese Academy of Sciences; this delegation included spouses.

This account may seem overly long, but it is a reflection of an unusual and sudden increase in scholarly mobility which demanded a considerable investment in time and goodwill and which should lead in the future - as the Chinese institutions become stabilized and as Americans learn Chinese - to a more normal interchange of students and scholars of all ages.

Our visitors from the ETH - an institution that was founded in 1855 and followed initially a developmental pattern not too different from that of MIT - were more interested in comparing practices relating to promotion and tenure, interdepartmental laboratories, admissions to undergraduate and graduate education, UROP, relations to industry, etc. In this sense their visit resembled our biennial meetings between administrators at MIT and Cal Tech. Relations between MIT and the ETH suffered a relatively short interruption during World War II but since then faculty members have been visiting professors both there and here, and thus there were no great surprises for either party except a deeper understanding of how the different funding patterns in the two countries affect planning.

Last year's Provost's report dealt in some detail with MIT's reaccreditation, a process which usually occurs every 10 years. In contrast to the 1969 review, which was rather stylized in the midst of a rather turbulent period in American higher education, the 1979 review was focused on four themes which represent continuing concerns in the area of academic policy, to wit basic educational requirements, the evolution of interdisciplinary forms, the role of computers in MIT education, and career paths and career expectations of MIT students and alumni. The NEASC 10-person visiting team under the chairmanship of Dr. Guy Stever took the preparation of their report as seriously as they had taken their 3½ day visit to MIT. They commented in detail on MIT's goals, on the four themes, on UROP, IAP, and the MIT-Wellesley Exchange, on alternate Freshman Path, on faculty and student concerns, on women faculty and student concerns, and on minority student and faculty concerns. Certain excerpts from the accreditation report deserve to be quoted here even though the entire report was made available to the MIT community in the February 27, 1980 issue of *Tech Talk*.

"It is worth our time here to give a simple statement of those goals as presented to the visiting team. 'In seeking to provide an education that unites application with principle, the technical with the perspective, scientific knowledge with human and social understanding, MIT has become a special kind of university. MIT's goal is to provide students not only with a solid understanding of a professional field, but also with a rich, humanistic background for effective career achievement and personal growth. Teaching and research form an essential and mutually reinforcing relationship at MIT, with many opportunities for students and faculty to participate together in research. The availability of multidisciplinary resources enables the Institute to address complex societal issues and to develop new insights into traditional disciplines. In some of these areas, MIT often collaborates with government, industry, and other educational institutions.'

The goals of MIT are well-understood by all concerned and, in those areas where clear attainment of the goals has been achieved, MIT has served society very well, indeed. The attempt to reach some of its goals is the source of some of MIT's problems, none of them unmanageable, but some serious in nature.

For example, MIT's preeminence in science, technology and some social sciences has, almost inevitably, produced an educational imbalance in which other disciplines, particularly the humanities, suffer by comparison. Similarly, MIT's emphasis on problem solving has encouraged the Institute to develop interdisciplinary centers which operate in a state of tension, some of it not always productive, with departments and other more permanent administrative units. Finally, MIT's success in its pursuit of excellence contributes in a major way to the pressures felt by the entire MIT community, but most intensely by women and minorities, whose presence in numbers at MIT is relatively new and disproportionately small. These problems will be discussed in greater detail later in the report.

On the positive side of all this, there is the clear belief held by many members of the Corporation and the administration, and many of the faculty and students as well, that the best education results from this close contact with up-to-date, real world scientific and engineering problems. There is

a sense of confidence and power given to all of the community that they are involved on a broad frontier. They feel proud to examine the problems of science and technology not only from the disciplinary points of view, but also from the point of a concerned society, to make sure that advances fit the needs and wishes of society.

Stemming from all of this is a very high pace of activity, often described by such terms as "a high pressure environment." This environmental effect spills over to students and their education, in fact to everybody associated with MIT. Many believe that it is a good thing, for it forces all concerned to do their best and to stay in the forefront, both in research and in education. On the other hand, some believe that many problems stem from this extreme environment. It certainly must be considered in all decisions made by MIT educators. In remaining elements of our report, this high pressure atmosphere will often be referred to.

. . . MIT has clearly stated and understood goals, and exudes a very clear sense of purpose and direction.

In spite of the many problems about which we heard, MIT is a cohesive campus. The Corporation understands the goals and purposes and the methods of education of MIT, and they approve in those areas where MIT differs from other universities. The intense professional work atmosphere of MIT is enjoyed by most of the participants, even though some people are turned away from MIT both as faculty members and as students, preferring a different atmosphere. MIT is conscious of all of its major problems. The only problems that the Visiting Team discovered which were not already under attack or well known to the administration were relatively minor ones.

MIT is still persistently tackling some of the problems which it has had for many years and there seems no flagging in the interest of solving them."

It goes without saying that the NEASC approved MIT's continued accreditation for a period of 10 years. Among the bodies that discussed this report in some depth were the Academic Council, the Committee on Educational Policy, and the Executive Committee of the Corporation. Responsive actions were taken in several instances; other issues which needed further discussion and study are under consideration by the relevant bodies of the MIT faculty and administration and in particular by the CEP.

Little purpose would be served were this final report of this Provost to attempt a summary of the major events and changes in MIT's academic life during the seventies. The yearly reports by the President and Chancellor have done justice to many issues. The increasingly complex fabric of the institution reflects both the evolution of Science and Technology and the increasing needs of our own and other societies to make effective use of the accumulated knowledge. These developments lead not only to more research in the established disciplines but also to new laboratories, facilities, centers, programs and even the appearance of a college or two. They also demand that the Institute be flexible in responding to the career aspirations of its students; that it be able to recognize appropriately the steadily enhanced quality of its faculty; that it provide new opportunities for young colleagues, be they engineers, natural and social scientists, managers, architects, or humanists; that it provide an environment that is favorable to many forms of creativity; and that it resonate to diverse human values. It was this experience of dealing with scholarship, with novelty, with colleagues of all ages that made being a Provost fun.

WALTER A. ROSENBLITH

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 continued to be responsible for the general direction of the Laboratory. At the same time, he headed the research effort on learning and reasoning by analogy. Professors Berthold K.P. Horn and David C. Marr led complementary efforts on computer vision. Professor Horn and his group have concentrated on the semantics of gray-level intensity values, while Professor Marr's group has largely been occupied with gray-level intensity changes. Dr. John M. Hollerbach directed research on computer-controlled, multiple-joint manipulators and other aspects of robotics research. Professors Randall Davis and Carl E. Hewitt have been concerned with different aspects of distributed problem solving and parallel computation. Professor Marvin Minsky worked on the development of general theories of artificial and natural intelligence. Professor Gerald J. Sussman and John Holloway have led work on the problems of integrated circuit design. Richard D. Greenblatt, Thomas F. Knight, and Mr. Holloway have continued their work on computer systems.

The Laboratory's 90 members included a total of 11 faculty, 48 research and support staff, and 31 graduate students. They were involved in research activities which were funded during the past year by the Defense Advanced Research Projects Agency, the Office of Naval Research, the Air Force Office of Sponsored Research, the Xerox Corporation, the Jet Propulsion Laboratory, and the International Business Machines Corporation.

Image Understanding

Professor Horn's group has made a detailed study of the problems associated with computing the shape of visible surfaces from their gray-level shading. In particular, they have formulated the *image irradiance equation* which relates the orientation of a surface patch and the directions of the light source and viewpoint on the one hand to brightness values on the other. An important variable in the equation is the function defining the reflectance of the surface material. 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.

One important application of these theoretical insights is to the problem of shading maps to facilitate human perception of surface topography. Shaded maps are most important when the interpreter's time is limited (as in aviation), for users that are not trained cartographers, and for small-scale maps, where contour lines degenerate into tangles. Unfortunately, shaded maps are expensive to produce as they require skilled artists with good insight into cartography. The reflectance map is the first representation to be devised which provides a common basis for the evaluation of the various possible methods for automatically generating shaded maps. Professor Horn has shown how the contributions of the principal map makers of the past can be critically analyzed in terms of the reflectance map. This led to the development of an efficient method for providing shaded overlays which depends on a lookup table containing sampled values of the reflectance map.

A second application of the image irradiance equation and the reflectance map representation is to satellite imagery. Previous work centered on the development of synthetic images for automatic registration and the construction of albedo maps (which factor out ground slope and sun position) so that intensity is solely a function of ground cover. A crucial step in this scheme is the generation of high quality synthetic images, and this is made difficult by the substantial

attenuation of visual signals by atmospheric scattering. Together with his student, Robert Sjöberg, Professor Horn has demonstrated that although understanding the effects of the atmosphere is a difficult task, the adoption of even simple models can provide substantial improvement over results obtained with no model. In particular, they showed how the abundance of shadows cast in mountainous regions can aid in the determination of path radiance.

Finally, Professor Horn and his students have developed a technique of exploiting the reflectance map to recover surface shape from a single viewpoint but with multiple light sources. They call the technique *photometric stereo* to contrast it with traditional stereo. William Silver has implemented a system which can quickly compute highly accurate surface shape from three images of matte objects. Professor Horn and Dr. Katsushi Ikeuchi have extended the scope of photometric stereo to metallic objects using distributed light sources. The ideas are being further developed with a view toward isolating objects in a parts feeding bin. The theoretical challenges to be faced include reflections and occlusions.

Recently, Professor Horn and his student, Brian Schunck, have begun to investigate the determination of optical flow from the image irradiance equation. Optical flow refers to the instantaneous positional velocity field which is generated by moving in a textured environment. It has been shown by other researchers that the optical flow can be used to segment a scene and to compute surface layout, but methods for computing the flow field have not previously been devised. The current system has proved to be resilient on synthetic images, and work is beginning to extend the theory to real images.

Natural Vision

Professor Marr, working with his student, Ellen Hildreth, and Dr. Tomaso Poggio of the Max Planck Institut in Tübingen, Germany, has suggested that the first stage of human visual processing locates the zero-crossings of the Laplacian of an image after convolution with a suitable 2-D Gaussian filter. Intensity changes occur over a wide range of scales and are detected through a small number of channels each of which is associated with an appropriate size of filter. Previous psychophysical evidence suggested that there are four separate channels at each retinal eccentricity, the filter sizes scaling linearly with eccentricity from the fovea. Professor Marr, Ms. Hildreth, and Dr. Poggio have shown that their theory can neatly account for the so-called vernier acuity of humans if an additional smaller, fifth channel is postulated which has roughly half the size of the next smallest.

The *zero-crossing map* is a representation of the intensity changes detected by these channels, and it records their position and slope and groups nearby zero crossings into blobs, bars, or edge segments. Progress has been made towards the goal of showing that the zero-crossing representation is complete by proving generalizations of Logan's theorem in signal theory. Additionally, Professor Marr and Dr. Shimon Ullman have investigated primitive motion computation on the basis of the theory sketched above. They suggest that the X-cells of the human retina carry the filtered Laplacian output, which is a sustained response, while the Y-cells carry its time derivative, which is transient. This theory has been the subject of detailed study by Dr. Ullman and Dr. Jacob Richter, who qualitatively confirmed it and then developed a refined version which embodies a detailed theory of the role of the amacrine and bipolar cells in early visual processing.

The work on zero crossings of the filtered Laplacian was originally stimulated by the development of a theory of human binocular stereo vision by Professor Marr and Dr. Poggio. Over the past year, Dr. Eric Grimson has completed a new implementation of the theory and has substantially improved the statistical analysis of its performance. The new algorithm has been thoroughly tested on random dot stereograms and on a small number of simple natural scenes. Work is currently starting on detailed experimentation with the stereo algorithm on complex natural scenes, both to strengthen the theory and to develop the details of the next stage of visual processing.

The stereo algorithm computes disparity, which translates into relative depth, at those places where a zero crossing in both the left and right image is matched. The problem then arises of interpolating a smooth surface from the relatively small set of points in the 2½D sketch at which depth is given explicitly by the stereo algorithm. Dr. Grimson has developed a theory that this

problem can be viewed as the minimization of an appropriate performance index subject to the given boundary conditions in the sense of modern control theory. The novelty is that Dr. Grimson insists that the performance index should be a seminorm and has suggested the use of quadratic variation. This has been implemented in the form of a local parallel algorithm and has been successfully tested. Recently, Drs. Michael Brady and Grimson have shown how similar ideas can be used to construct a theory of the perception of subjective contours.

The increasing interest in human perception of complex natural scenes and motion has placed great demands on the processing power available. Now that the zero-crossing theory and the details of implementation appear to have stabilized, work has been started on constructing hardware realizations of them. Dr. Keith Nishihara and Noble Larson have constructed a device to compute zero crossings and stereo matching. In addition, John Batali has designed an LSI chip to compute the position and slope of the zero crossings.

Robotics

Typical industrial robot arms have six degrees of freedom to enable them to be placed at an arbitrary point with arbitrary orientation. The motion of a distal joint depends on those proximal to it and this makes the equations of motion highly complex. Various suggestions have been made for simplifying the equations of motion, such as parameterizing some of the variables, such as joint position or velocity. The configuration-space control scheme developed by Professor Horn and Dr. Marc Raibert was aimed at solving this problem. Recently, however, Dr. Hollerbach has developed a Lagrangian formulation of the equations of motion as recurrence relations, and has shown that they lead to an exact solution in linear time.

It is the ordinary human abilities which are unbelievably difficult to automate. One such ability is the planning of motions in a world of obstacles so as to reach some goal without collision. Dr. Tomas Lozano-Perez has developed a system of wide generality which constructs a hierarchical tessellation of space and efficiently computes paths and safe positions for a polyhedral object in terms of configuration-space representations.

For a robot to perform compliant motions such as closing a door or using a screwdriver, it is necessary to control position along some dimensions and force along the remainder. The dimensions sum to the number of dimensions available in configuration-space. Matthew Mason has further distinguished natural and artificial constraints on manipulator motion. For example, the fact that the screwdriver cannot be pushed down along the length of the screw without turning is a natural constraint, while keeping the screwdriver in the screw groove is an artificial constraint, which it is necessary to impose for screwdriving to be successful.

The joints of current electrical robot arms are driven by dc motors situated at the joints. They are typically heavy and not only obstruct movement but substantially increase the inertia of the joint, thereby making fine motions more difficult to accomplish accurately and quickly. One solution to this problem has been proposed by Messrs. Larson and Mason. They have designed a motor which acts like a dc motor when in slew mode but permits the fine control of a stepping motor at slow speed. An alternative is to emulate the tendons used by humans. Dr. Hollerbach has designed a three-degree-of-freedom tendon driven shoulder which closely models that of a human. Construction is nearing completion. Danny Hillis has constructed a four-joint human sized finger which has eight coupled tendons. He also has developed a touch sensor based on a thin semiconductor rubber film which resolves 256 points per square centimeter.

Learning from Experience and Reasoning by Analogy

Professor Winston has elaborated his theory of reasoning by analogy such as people do when they analyze situations in medicine, law, economics, and engineering. He has developed a representation for the meaning of complex situations such as skeletal story plots and abstracts of research articles, which involve causal dependencies and other relations between relations. The representation is a development of case structures devised by linguists for the meaning of English sentences. The current system consists of the following parts: a classification-exploiting hypothesizer that searches memory for situations that are likely to be similar to a new, given situation; a cause-dominated matcher that measures the similarity between two situations by finding the best possible correspondence according to the causal framework determined by

the situations themselves; a rule system that reaches conclusions about a given situation by using knowledge found in a remembered situation; and an experience-driven verifier that checks conclusions. The results of various test applications of these theories indicate significant promise for the use of the analogy theory in information retrieval of technical material.

Robert Berwick has completed work on a program that can acquire the syntactic knowledge (in the form of grammar rules) to parse a large subset of English by examining only simple instances of English sentences. The target rules to be learned were originally developed within the Laboratory by Dr. Mitchell Marcus for his thesis. Currently, the program can discover about 65 percent of the grammar rules developed by Dr. Marcus. The range of the program has been extended so that it can infer the context-free structure rules required for the example language presented to it. About a dozen of the phrase structure rules for English have been successfully acquired.

Expert Problem Solving in Programming

Drs. Richard Waters, Charles Rich, and Howie Shrobe have analyzed the logical structure of programs. They have devised a representation called a *plan*, which is a language-independent representation for a program. It abstracts away from the syntactic details of the programming language, representing control flow and data directly. The central idea is that typical programs are built up in a small number of stereotyped ways by what are called plan-building methods.

The power of the program analysis system is demonstrated by the fact that it can produce Plans for COBOL programs as well as for LISP and FORTRAN programs. Dr. Waters also has constructed a coding module which produces LISP code from a Plan. It has been tested on several dozen Plans, including some which were produced by automatically analyzing COBOL and FORTRAN programs. The LISP programs produced range from several lines to several pages long.

VLSI Design

Professor Sussman, Mr. Holloway, and their colleagues, Dr. Shrobe and Mr. Knight, have made considerable progress in their research into techniques and tools for VLSI design. Together with Dr. Alan Bell of the Palo Alto Research Center of Xerox Corporation and Dr. Guy Steele, they completed the design and implementation of a single chip microcomputer, called SCHEME-79, which has 32 bit data paths and which directly interprets a typed-pointer variant of SCHEME, a dialect of the LISP programming language. The chip implements an automatic storage allocation system for "heap allocated" data and an interrupt facility for user interrupts implemented in SCHEME.

A central problem in the development of the highly complex circuits typical of VLSI design, including both general programming language interpreters and the special purpose devices alluded to earlier in the description of our vision research, is keeping a record of the various decisions which have been taken regarding the layout of the circuit and the constraints which the various layers impose. Dr. Shrobe has developed the Daedalus system, which embodies a library of standard parameterized circuits, such as NAND gates and registers, and features "menu style" interaction with the LISP machines constructed within the Laboratory to facilitate this kind of research. The Daedalus system generates multiple colored views of a circuit at different levels of resolution.

Parallel Computing and Distributed Problem Solving

Professor Davis has studied some of the fundamental issues that must be faced in distributed problem solving. Motivations for distributed problem solving include both economic forces (which suggest connecting many small computers together to work on a common goal), as well as arguments based on reliability and graceful degradation in performance if one of many machines stops functioning. One idea is that control needs to be devolved from a central location to ensure that no individual processor is unique, and therefore constitutes a threat to the reliability of the system as a whole. Professor Davis has developed the idea of the contract net in which tasks are viewed as contracts between processors. This formalization of some of the ideas of contract-letting is one specific approach to the more general conception of organizing groups of

processes along the lines used in human organizations. Professor Davis is concentrating his investigations on a small number of specific systems which naturally demand distributed processors to cooperate. One such problem concerns the development of a network of sensors, such as weather-forecasting ships at various locations in the ocean.

Creating more knowledgeable computer systems will require vastly increased computational resources. Professor Hewitt and his students are investigating the issues surrounding the creation of parallel hardware to meet this need. They also exploit a social metaphor, that of worker bees in a hive. A central problem in any multiprocessor system concerns the topology of interconnections between the individual processors, and this in turn determines the lengths of the wires between processors. Some researchers have suggested placing processors at the vertices of an n-dimensional cube so that the maximum number of hops between processors is the logarithm of the number of processors. Unfortunately this topology has the disadvantage that almost all the wires are extremely long, which is disadvantageous in VLSI systems. In order to deal with this problem Professor Hewitt, in collaboration with Professors Halstead and Zippel, has developed the idea of using a folded n-dimensional hypertorus, which can be visualized as wrapping opposite sides of the n-cube to make them adjacent. Jeff Schiller has constructed a test bed implementation based on three of the Laboratory's LISP machines, and a simulator for a 64-node apiary using the folded cartesian hypertorus geometry of interconnections completed. This has enabled pilot studies of the important idea of work sharing and dynamic load balancing to be started. Recently Phyllis Koton has constructed a communications VLSI chip called PORTAL-0 to facilitate further experimentation with the "Apiary."

The Computing Environment

Intelligent information processing places unusual demands on computers. Consequently, Messrs. Greenblatt, Knight, and Holloway, and their colleagues, have designed a computer called the LISP machine that gives its users more symbol-manipulation and list-processing power than has ever been available before. 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.

During the past year we have completed the construction of the thirteenth LISP machine. All of the existing machines are linked together to demonstrate that collections of inexpensive, connected "personal" computers in local networks are superior to large, expensive time-shared machines. The linking is through an eight-megabit packet-oriented cable system known as the CHAOSNET. The CHAOSNET links all 13 LISP machines, as well as five PDP-10s, two ether net gateways, and other miscellaneous computers and terminal concentrators on .65 miles of cable. The technology is such that the system can support as many as 100 communicating computers before reaching intolerable performance deterioration.

To further increase performance of the LISP machines, Mr. Greenblatt has completed a compiler which generates microcode from a user's LISP code. The compiler has successfully completed its initial tests and should soon be generally available. In addition, Howard Cannon, David Moon, Michael McMahon, Richard Stallman and their colleagues have greatly enhanced other parts of the total system.

Basic Theory

Professor Minsky has continued the development of his *society of mind* theory, in which 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.

It is hoped that the approach may illuminate the psychological theories of Piaget and Freud, as well as the coherence of Artificial Intelligence theories, which have not previously attempted to consider the kinds of problems that must be confronted by a whole "personality." 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. The censors and critics of the hierarchy must settle conflicts by referring to early developed self-images.

Whether or not the theory is psychologically productive, the work has already suggested new ways to organize very large knowledge-based computer programs. Recently, it has produced some novel ideas about building large, active computer memories. These new memory structures may turn out to be very useful for the representation of kinds of common-sense knowledge that have been hard to deal with in conventional systems. Several students are implementing computer models of their own versions of the theory.

Recently, Mr. Greenblatt and Dr. Lucia Vaina proposed the idea of thread memory to model various aspects of concept learning and anomie aphasia. Dr. Vaina has now initiated a study of semantic memory which is oriented toward the design constraints on a memory that is capable of carrying out information processing tasks of the following kind: the assembly of descriptions of objects, the assembly of descriptions of actions as represented in the use of objects or their function, and certain limited kinds of inference.

Education

The LOGO Group, under the direction of Professor Seymour Papert, concentrates on enhancing education through the application of both theoretical and technological developments in computer science. Most of the group's activities involve collaboration with the Division for Study and Research in Education (DSRE).

Dr. Sylvia Weir from DSRE, together with Professor Papert, Jose Valente, and Gary Drescher has been drawing attention to the role which computers might play in the management of the physically handicapped. Work has continued on the application of computer-based techniques to maximize the acquisition of spatial and linguistic skills in severely cerebral palsied children, to serve the educational and therapeutic needs of this population. This research requires the development of a set of computer based diagnostic tools for use with physically handicapped persons which could contribute to the provision of a functional specification of subcategories of cerebral palsy. It is expected that this will, in turn, inform our theories of cognitive development in normal individuals.

PATRICK H. WINSTON

Cell Culture Center

The Cell Culture Center at MIT 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 MIT, Dr. Richard L. Davidson from 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 in the investigator's own laboratory. The Center is working directly with individual scientists on basic research problems and, in addition, is conducting an active program in the development of new techniques for large-scale cell and virus production.

Production

During the period of January 1, 1979 to December 31, 1979, the Cell Culture Center provided cells and/or virus materials to 44 research projects throughout the United States. Roller bottle production remained essentially the same as last year (104 vs 105 percent of our total capacity). Suspension culture production (50 percent) and virus production and purification (72 percent)

were both up slightly from last year. Examples of projects completed during this period include: 1,685 roller bottles of Balb 3T3 and SV-3T3 cells for Massachusetts General Hospital, Boston; 5,577 roller bottles of SV-80 cells for University of Illinois at Urbana; 800 roller bottles of 2^oCEF cells for Sindbis virus production for The Johns Hopkins University in Baltimore; 900 roller bottles of 2^oCEF cells for Sindbis and RSV production for MIT; 750 roller bottles of RAG cells for Children's Hospital Medical Center, Boston; 300 roller bottles of SK-MEL 37 cells for Sidney Farber Cancer Center, Boston; and 120 roller bottles of SV-80 cells for the University of California at Stanford.

Cost Apportioning Program

The Cost Apportioning Program continues to be a successful operation. Under this policy, all users are required to pay for the cost of all consumable materials used for their projects. The Center is receiving nearly 100 percent return on all expendable materials billed.

Research and Development

Process Development and Delivery of Human Fibroblast Interferon. This is a joint project involving the MIT Cell Culture Center, Flow Laboratories of McLean, VA, and New York University School of Medicine. The role of the Center in this project is to conduct research and development designed to improve the current level of technology in the area of large-scale fibroblast interferon production. The large-scale production will take place at Flow Labs and purification of interferon will be accomplished at New York University School of Medicine.

Microcarrier Use for Mammalian Cell Propagation and Interferon Production. One research project which involves optimization of conditions for human interferon production with microcarrier-grown cells, using a superinduction procedure, has been in progress for the past year. A large number of parameters were examined for their effects on both cell growth and interferon yields. Optimal concentrations of inducer and antimetabolites were established, and it was shown that both priming (addition of a small amount of interferon for a period of time prior to induction) and temperature control were essential for obtaining consistently high-titered interferon production. Over the one-year period, interferon yields were increased from approximately 5,000 units to more than 20,000 units/10⁶ cells.

An important part of this project involves research relating to the rational scale-up of the microcarrier system. In this study a number of important physical parameters e.g., shear forces and O₂ consumption, are being examined for their effect on cell growth during scale-up.

Biotechnology in Drug Development. Another research project under way at the Center involves the use of computer-linked instrumentation to monitor and control mammalian cell culture for the production of interferon and other cell products. This computerized system, which is interfaced with a 14-liter fermentor, has just been completed, and will be used to optimize conditions for cell growth and interferon production during scale-up.

Human Cell Culture Production of Opsonic Protein. This project, which is just getting under way, has the overall goal of utilizing microcarrier-grown human cell cultures for the production and subsequent purification of opsonic protein. This protein, also known as alpha-2-surface-binding glycoprotein and fibronectin, has been shown recently to be effective in the treatment of septic shock. The investigation will involve screening a number of human cell types for their ability to produce opsonic protein, exploring the influence of cell age and cell cycle on this process, and optimization of environmental conditions to obtain the maximum yield of protein.

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 provided students with excellent preparation for vocations that require a broad knowledge of the techniques

of cell culture and animal virology. During 1979-80, two students successfully completed the program and two are enrolled for the current term.

PHILLIPS WESLEY ROBBINS

Center for Advanced Visual Studies

During 1979-80 the Center for Advanced Visual Studies (CAVS) continued working toward its goals of creating and teaching art involving science and technology, and developing and articulating new media which will constitute the art and creative life of the future. This year the Center hosted 25 artists whose individual work in collaboration with MIT scientists and engineers is one major subject of support at CAVS. Another concern is group projects among artists and among artists, scientists, and engineers. Besides artistic work, project investigation, and artistic research, the Center is committed to education at several levels. The Center's contribution to the Master of Science in Visual Studies program has propelled inter-media education and interdisciplinary graduate studies. A new type of artist -- one who combines artistic ambition with technological sophistication -- has emerged already from years of work in the program. Association with sections of the School of Architecture and Planning has been productive and inspiring to all participants in the program.

Undergraduate and graduate education involved about 200 students in various academic pursuits during the year. The Center was involved in both formal MIT subjects as well as informal teaching and special projects. Activities ranged from environmental design/environmental poetry (Mark Mendel) to Advanced Visual Design/laser and computer programming and advanced artists electronics (Paul Earls) to a Center presentation series, "The Artist Speaks" (moderated by Paul Earls), in which Center artists presented documents and ideas about their work and objectives. Other areas of interest included interactive visual telecommunication (Aldo Tambellini), new media/media culture criticism and alternatives (Antonio Muntadas) and film theory in new German cinema (Wendelin Glatzel). In fall 1979 Mr. Earls and Elizabeth Goldring presented a series of discussions on Art and the Environment, which is at the heart of the Center's concerns. Center fellows participated, and invited guests from the Institute and from outside MIT complemented fellows' and students' presentations.

Interestingly, but not surprisingly, the most popular subjects were elementary introductory subjects: Basic Photography for Architects (Nishan Bichajian); Life Drawing and Still Life (Mr. Bichajian); and Advanced Figure Drawing (Mira Cantor).

The CAVS group of artists has been forcefully inspired by new fellows who could be invited with the help of Rockefeller Foundation grants; among them: Piotr Kowalski, Chryssa, Yvonne Rainer, Harriet Casdin-Silver and Mr. Muntadas. The presence of these artists has helped to articulate and broaden new media. This becomes particularly evident in Ms. Casdin-Silver's work in holography as an artistic medium and Mr. Kowalski's investigation of time as artistic material with the help of computers and other electronic techniques.

Partners in the MIT science and engineering community who have continued their collaboration and response with CAVS artists have been, among others, Institute Professor Emeritus Harold Edgerton, Professors Woody Flowers, Ain Sonin, Walter Lewin, Jerome Lettvin; and of the School of Architecture and Planning, Professors Nicholas Negroponete, Richard Leacock, Muriel Cooper, and Ronald MacNeil. Fruitful collaboration has occurred between Center artists and Educational Video Resources (EVR) personnel and facilities. Dr. Edwin Taylor has been a conscientious as well as enthusiastic host to many CAVS projects.

Some outstanding individual artistic accomplishments were Mr. Kowalski's Time Machine #1 displayed at the Feldman Gallery in New York and Ms. Casdin-Silver's holographic portrait, "A Woman," displayed in her one-woman exhibition in the CAVS section of the 1979 Vienna Biennale. Ms. Casdin-Silver's holographic work has been acknowledged by her appointment as a consultant on holography to the Rockefeller Foundation.

Ms. Rainer's film "Journeys from Berlin, 1971" -- edited during her time as a fellow at CAVS -- became a major success in this country and at film festivals abroad. Other accomplishments by Center fellows: Mr. Muntadas' video installation at the Guggenheim Museum, "Pamplona-Grazalema," was on the theme of the bull as a symbol of Latin culture; Mr. Muntadas' and Mr. Tambellini's telecommunication events involving cities around the world via satellite and slow-scan telephone links. Joan Brigham (in cooperation with former CAVS fellow Stan VanDerBeek) staged a steam-and-projections event at the Whitney Museum in New York. Chryssa had two dramatic one-woman exhibitions -- one at the Musée de l'Art Moderne de la Ville de Paris and one at the National Pinacothèque in Athens, Greece.

Out of the conviction that large-scale art demands more than one artist/scientist/engineer, comes the tendency toward group projects at CAVS. The Center's participation in the Vienna Biennale for Graphic and Visual Arts brought to that city Ms. Casdin-Silver, Mr. Earls, Ms. Goldring, and Otto Piene. Two indoor performances by Mr. Earls and Mr. Piene, and the latter's inflatable installations and sky events, added progressive elements to the Vienna show of excellence.

In the fall of 1979 Mr. Earls, Ms. Goldring, and Mr. Piene participated in the Guadalajara Fiestas de Octubre. The interplay between two old cultures and modern art and technology became the underlying theme of the CAVS contribution.

Sky art has been a medium of increasing fascination to Center artists and other artistic circles since Mr. Piene staged his first large-scale sky events at MIT 12 years ago. The resonance throughout the world inspires the plan for a sky art conference to originate from CAVS in 1981.

Promising fund-raising efforts for this project have been under way for a year. The conference will move from MIT to major cities internationally and eventually, after three years, return to Boston. It is to encompass flying sculpture, large-scale light (laser) art, space art (traveling in space), induced sky/space phenomena, and telecommunication. The participants to define the facts and possibilities will be artists, scientists, scholars, engineers, representatives of space business and government agencies. Sky art is expected to become an encompassing form of environmental art, which will of necessity unite the interests and practice of art, science, and technology.

An energetic international exchange of fellows and visitors has characterized -- more than ever -- the artistic and intellectual life of CAVS. Chryssa, Mr. Kowalski, Ms. Rainer, Mr. Tambellini, and Mr. Piene had substantial exhibitions in Europe; Carl Nesjar designed and built his "Memorial Ice Fountain" at the Lake Placid Winter Olympics for the Norwegian Sonja Henie Foundation; Don Thornton is on leave to teach holography in Japan; and Mit Mitropoulos is arranging media events in Belgium and Greece. Mr. Piene's history as the co-founder of Group Zero in Europe in the late 1950s was reviewed by two major Group Zero retrospectives: at the Kunsthhaus Zurich and at the Musée Royal des Beaux Arts in Antwerp.

Mr. Earls' involvement in the "Dreamstage" exhibition (on human sleeping behavior) climaxed in the appearance of "Dreamstage" at the Boston Science Museum.

Visitors from abroad at CAVS included Pontus Hulten, head of the Centre Pompidou/Beaubourg modern art museum in Paris, Mel Alexenberg, president of an Israel art college, and many American museum directors and media program directors. Charlotte Moorman gave two concerts at the Center.

Publishing efforts have been productive: Articles on Center work and Center artists appeared in *Flying Colors*, *Omni*, *The New York Times* and numerous French and German magazines. "Centerbeam," edited by Mr. Piene and Ms. Goldring will be published by MIT Press this September.

Center fellows were given the following grants and awards: NEA workshop grant to CAVS; individual NEA grant to Mike Naimark; Massachusetts Foundation grants to Ms. Cantor, Betsy Connors, and Mr. Muntadas; the first Wiesner Award to S.M.Vis.S. graduate student Bill Parker.

The new Artscience Gallery at the Chicago Museum of Science and Industry purchased some major works from Center fellows. The most valuable support for fellowships and related projects has

Center for Cancer Research

been provided by a major grant from the Rockefeller Foundation's arts program whose commitment to CAVS work has meant encouragement and reassurance to us.

OTTO PIENE

Center for Cancer Research

The year 1979-80 has been one of rewarding progress for the Center for Cancer Research, highlighted by the presentation of the U.S. Steel Award in Molecular Biology of the National Academy of Sciences to Professor Phillip A. Sharp for his discovery of messenger-RNA "splicing," a finding that has revolutionized our understanding of gene action.

Equally exciting has been the appointment to the MIT faculty of Dr. Susumu Tonegawa, one of the world's foremost molecular immunologists. Dr. Tonegawa, who will arrive at MIT on July 1, 1981, will occupy laboratories newly remodeled through grants from the National Cancer Institute and from MIT sources, expanding the research space of the Center by about 3,000 square feet.

Dr. Thereza Imanishi-Kari, currently at the University of Cologne, has been appointed as Assistant Professor of Immunology in the Department of Biology; in the Center, she will replace Professor Paul D. Gottlieb, who has accepted a professorship at the University of Texas.

A teaching laboratory for undergraduate courses in areas related to cancer is also being made ready for use starting in February 1981.

The Center for Cancer Research has been host to several visitors in the past year: Dr. Peter Besmer, Sloan Kettering Memorial Institute, New York, and Dr. Naomi Rosenberg, Tufts University Medical Center, Boston, have been guests of Professor David Baltimore; Professor Howard Gershman of Case Western Reserve University, Cleveland, Ohio, has been visiting Professor Phillips W. Robbins.

Among the many research projects conducted in our Center I should single out two. The first is Professor Robert Weinberg's group's studies in the transformation of normal cells into malignant cells by DNA isolated from cancer cells. The second is the success of Professor David Housman's group in isolating human DNA from mixtures of DNA extracted from human-mouse or human-hamster cell hybrids. These studies may open the way to the ultimate identification and isolation of genes responsible for human cancers.

SALVADOR E. LURIA

Center for Cognitive Science

INTRODUCTION

Cognitive science is concerned with the study of those mental capacities and biological mechanisms which underlie human thought. The major focus of its intellectual activity is "How is knowledge represented mentally?" It may be useful to pause momentarily over the impact of this question.

In an article entitled "Vision and the Brain" (*Bulletin of the American Academy of Arts and Sciences* 31:28, 1978), David Hubel observed:

"... we are led to expect that each region of the central nervous system has its own special problems that require different solutions. In vision we are concerned with contours and directions and depth. With the auditory system, on the other hand, we can anticipate a galaxy of problems relating to temporal interactions of sounds of different frequencies, and it is difficult to imagine that the same neural apparatus deals with all of these phenomena...for the major aspects of the brain's operation no master solution is likely."

The work in mental representation that is on-going in the Center may be seen as directly in line with Hubel's conclusion that the brain is not an undifferentiated and unstructured organism. Thus, Center scholars work primarily, though not exclusively, in three specific areas; namely, language, vision, and conceptual endowment. The underlying goal of the research is to discover the principles according to which each of these faculties is organized. The Center researchers conceive of this work as taking place at three separate levels. The first level is one where the abstract structure of a particular cognitive capacity is characterized. For example, the ability to speak a language is a cognitive capacity. The task of the first level is to formulate the abstract principles which underlie that ability. The second level is concerned with the characterization of specific algorithms. These algorithms perform tasks related to a given cognitive capacity. For example, the cognitive ability to speak a given language includes the ability to determine whether or not a given string of words is a sentence in that language. Speakers do this with ease. The algorithmic level attempts to specify how they do it. The third level is concerned with determining how the neural mechanisms of the brain embody the algorithms which perform these tasks.

A specific example might be useful. Part of the language faculty of a speaker of English is the tacit knowledge that the appropriate question form of The man is here is Is the man here? However, it would be wrong to conclude that the rule required to form such questions simply moves the first occurrence of is to the front of the sentence. Such a rule would predict that the question corresponding to The man who is late is here would be the ungrammatical *Is the man who late is here? rather than the correct Is the man who is late here? Since children learning language never exhibit errors of the former kind, it is safe to assume that the question rule does not result from trial and error. Rather it results from a structural property of such sentences; namely, that the phrase The man who is late in the sentence The man who is late is here is structurally identical to the phrase The man in the sentence The man is here. The question rule that English speakers employ is sensitive to this structural identity and can be stated in terms of it. This property of rules of grammar being structure-dependent appears to be one of the crucial organizing principles of the language faculty. Moreover, since it is not learned, it must be innate. Thus, to return to Hubel's comment, it must in some indirect sense characterize the functioning of the neural apparatus of the brain dedicated to the language faculty. The work of the Center is devoted to formulating and studying such abstract principles and, ultimately, to placing them in a neural context. To paraphrase John Marshall in his reply to Noam Chomsky's "Rules and Representations" (in *The Brain and Behavioral Sciences* 3, 1-61, 1980) the Center is attempting to find a viable way in which results shared in linguistics, artificial intelligence, psychology, philosophy, and physiology can be made to bear upon each other.

This effort is not particularly new to MIT. Research in cognitive science has been pursued in a variety of departments and laboratories here for more than 30 years. Members of the Center for Cognitive Science are drawn from the Departments of Linguistics and Philosophy, Psychology, and Electrical Engineering and Computer Science; the Artificial Intelligence Laboratory and the Research Laboratory of Electronics; and the Division for Study and Research in Education.

In its second year, the Center has entered a period of transition from tentative projects and temporary administrative arrangements to one of continuing research and education. As with the field of cognitive science in general, the Center's activities are changing gradually from large, one-of-a-kind interdisciplinary conferences, heterogeneous seminars, and senior personnel exchanges to longer-term postdoctoral appointments, smaller topical workshops, and special interest seminars organized to explore particular subjects in depth. Several ongoing research programs which have emerged from the general interest in cross-disciplinary studies have received funding. A laboratory for psychological testing is being established, and committee work outlining a course of training in cognitive science is nearing completion.

We anticipate that these more permanent projects, together with others which will emerge in the near future, will comprise the Center's activities in the next few years as we try to provide a stable and continuing environment for research and training in cognitive science at MIT.

RESEARCH

Postdoctoral Fellows

During 1979-80, a number of young postdoctoral fellows in cognitive science have joined the Center under a program supported by a grant from the Alfred P. Sloan Foundation. In addition to continuing their professional training, these postdoctoral fellows participate in research with other members of the Center and contribute to seminars, workshops, and other Center activities.

Joint Seminar

Each term, the Steering Committee of the Joint Seminar selects a series of current papers to be discussed at biweekly meetings. The papers are distributed in advance and a designated discussant starts each meeting with a brief criticism of a paper's content and point of view. Whenever possible, the author of that paper responds to this critique as the first stage of a general discussion. These meetings have been highly successful as a means for conducting an informed discussion of recent work in cognitive science, and they provide a convenient occasion for communication among members of the local cognitive science community.

Topical Workshop

As mentioned above, the Center's public activities heretofore have consisted mainly of a number of interdisciplinary workshops on cognitive science. These workshops were supported by the Alfred P. Sloan Foundation as the first phase of its Particular Program in Cognitive Science. They proved invaluable for generating interest in cognitive science from within and outside the field. Two MIT workshops, held jointly at Endicott House on June 8-11, 1978, resulted in a book entitled *Biological Studies of Mental Processes* (David Caplan, Ed., MIT Press, 1980).

A plan for continuing the communicative spirit of these workshops has been initiated by scholars from five other Centers of Cognitive Science. The first of these topical workshops, with participants from MIT, Brown University, the University of California at Irvine, the University of Pennsylvania, Stanford University, and the University of Texas at Austin, was held May 24-25, 1980 at MIT.

Occasional Papers

One barrier to scholarly communication in an emerging field is the time lag in normal channels of publication. Moreover, the diversity of cognitive science results in papers of common interest appearing in a variety of special-interest journals or collections of articles. To help alleviate these problems, as well as to aid members of the Center in disseminating reports of their research, the Center for Cognitive Science has instituted a series of Occasional Papers in Cognitive Science.

Language and Mind Lectures

During the January 1980 Independent Activities Period, members of the Center's Language and Mind Curriculum Development project held a lecture series titled "Intelligence: A Series of Lectures." A list of lectures and their topics is included in the archival version of this report.

Research in Progress

Support for research and education in the Center comes from the Alfred P. Sloan Foundation, the National Science Foundation, the National Institute of Education, the National Endowment for the Humanities, and Institute contributions. Substantial support for cognitive science already has been derived from proposals to government agencies, and a number of additional proposals are pending or in the process of submission. Research projects in progress include the following:

Pre- and Postdoctoral Fellowships in Cognitive Science (Alfred P. Sloan Foundation, sponsor). An essential feature of the Center's present operation is the support of a select group of Fellows in Cognitive Science. In addition to the stimulus that these scholars provide to existing research programs, each fellow pursues his or her own research while at MIT.

Conceptual Change in Children and Adult Scientists (NSF/NIE, sponsor; Principal Investigator: Susan Carey). The first research project funded in the Center critically examines the parallels between conceptual development during childhood and conceptual change in the history of science. The project analyzes the development of children's differentiated concepts of weight, volume, and density in comparison to the development of the concepts of heat and temperature by adult scientists.

Multi-User Laboratory Computer Facility (NSF, sponsor; Principal Investigator: Edward Walker). One significant need of members in the Center has been a modern laboratory for psychological testing. Six members of the Center -- Dr. Joan Bresnan, Linguistics and Philosophy; Dr. Carey, Psychology and Division for Study and Research in Education; Dr. Jerry Fodor, Psychology and Linguistics and Philosophy; Dr. Jay Keyser, Linguistics and Philosophy; Dr. Molly Potter, Psychology; and Dr. Edward Walker, Cognitive Science Center -- identified their common needs for such a multi-user facility in a grant proposal to the National Science Foundation.

Funds were approved in January 1980 for a PDP 11/44 laboratory computer, together with modest system resources and local processing capability. An initial purchase of a TERAK microcomputer supports research by a number of graduate students and members of the Center, and the main system is scheduled to be installed during the coming year.

Grammatical Representation and Grammatical Processing (NSF; Principal Investigators: Dr. Bresnan, Ron Kaplan). The research objectives of this project are to investigate a linguistic theory of the mental representation of natural language and to develop and experimentally test computational models of the psycholinguistic processes that construct and interpret linguistic representations during the comprehension and production of speech.

Research is proposed to study the lexical encoding of grammatical relations and their semantic interpretation, to implement the computational model at MIT and derive measures of complexity from it, and to test and develop both representational and processing theories by psycholinguistic experimentation.

Administrative Collaboration with Other Centers of Research

In addition to the topical workshops referred to above, which involve collaboration between scholars at MIT and other Centers of Cognitive Science within the United States, arrangements for collaboration with centers of research in cognitive science are being made for the mutual exchange of students and researchers at the Centre Nationale de Recherche Scientifique (Paris) and the Max Planck Institute for Psycholinguistics (Nijmegen).

These exchange programs will involve occasional meetings and joint participation in appropriate research projects as well as both long- and short-term visits by workers from each participating institution.

The recent participation by a number of members of the Center in a "Conference sur la Psychologie Cognitive" held at Royaumont Abbey, near Paris, and visits to MIT by Drs. Angelika Kratzer, William Marslen-Wilson, and Lorraine Tyler of the Max Planck Institute, represent the types of interaction anticipated.

EDUCATION

The curriculum in cognitive science at MIT is composed of courses drawn from the regular schedules of departments. An undergraduate program in Language and Mind has been in existence since 1976, and a curriculum guide to graduate courses is distributed each fall. This guide is prepared by the Interdisciplinary Committee on Cognitive Science.

A complete general curriculum in cognitive science intended for consideration by other institutions of higher learning, as well as MIT, is being developed by members of the Center and of affiliated departments, under a grant funded by the National Endowment for the Humanities.

CONCLUSION

In the past year, the Center for Cognitive Science at MIT has matured. A number of research projects, a computer-controlled laboratory, a major program of pre- and postdoctoral training, and a curriculum study project have all been funded. In addition, the various seminars, workshops, and publications of the Center have taken on a permanent character.

The prospects for continued growth and funding of the Center's operations seem good, and we look forward with some optimism to the intellectual and administrative challenges of the coming year.

SAMUEL JAY KEYSER

Center for International Studies

During the past year, the Center for International Studies has continued to conduct research and analyses on contemporary policy issues that have significant technological aspects. These studies are mainly international in scope, although not exclusively so. Much of the year's work represents a continuation of long-term interests -- such as arms control and communications -- in which the Center has been engaged for most of its 30-year existence. But the program described here also reflects the attention being directed to issues -- such as energy and the environment -- that have more recently become prominent public policy concerns.

The fields of arms control and defense policy have remained areas of substantial Center activity. With support from the Ford Foundation, this Center program includes support of students and faculty from several MIT departments for a major graduate teaching program, principally in the Department of Political Science; significant research undertakings by faculty, students, and visiting scholars; and an active seminar series to stimulate discussions of current arms control and defense topics in the broader MIT community.

The program is directed by Professor Jack Ruina, Department of Electrical Engineering and Computer Science; other principal participating faculty are Professors George Rathjens, Ted Greenwood, William Kaufmann, Stephen Meyer, and Eugene Skolnikoff, all of the Department of Political Science; Professor Bernard Feld, Department of Physics; Professor Richard Lester, Department of Nuclear Engineering; and Amelia Leiss, Center for International Studies.

Specific research undertaken during the past year has focused primarily on US-Soviet strategic relations, with special attention given to the ways in which changes in weapons technology have affected the strategic balance. Work concerned air defense issues (carried out by Dr. Ruina), US force structure (Dr. Kaufmann), so-called gray area systems (also Dr. Ruina), MX missiles (Hugh Hinds, Visiting Scholar, Center for International Studies), and the Soviet weapons acquisitions process (Dr. Meyer). Other areas of prime concern were non-proliferation (on which

the work of Dr. Rathjens, Dr. Greenwood, and Dr. Lester concentrated), patterns of Soviet involvement in countries outside the Warsaw Pact (Dr. Meyer), and conventional arms transfers (Ms. Leiss). All of the above studies were carried out during the past year with support from a grant from the Ford Foundation for general support of the Center's work in this area.

Additional related work conducted during the year included a study by Dr. Ruina and K. Nagaraja Rao (Center for Policy Alternatives) of the manner in which less industrialized states develop indigenous arms industries, utilizing imported technology. The study focused especially on India, Israel, and Brazil and examined the effects, if any, that controls over the export of civilian or dual-use technologies would have had on the process. This study was funded by the United Nations, as was an analysis by Professor Lance Taylor (Departments of Economics and of Nutrition and Food Science) of the mechanisms by which the effects of increased defense expenditures by developing countries are felt through the economy, with particular emphasis on investment, income distribution, balance of payment, and growth rate.

Professor Hayward Alker, Department of Political Science, has conducted a study under National Science Foundation (NSF) support that explores the control of security problems from a very different perspective. In a study entitled "Reflective Logics for Resolving Insecurity Dilemmas," Dr. Alker is applying increasingly powerful logical mechanisms to data on attempts to resolve insecurity dilemmas -- i.e., situations where short-term individual security considerations contradict longer-term collective security interests. Dr. Alker is drawing his data from a range of situations, from "prisoner's dilemmas" to specific international conflicts. The Ford Foundation has provided funding for a conference on "Recent Scientific Contributions to International Learning about War Avoidance," which Dr. Alker is organizing in collaboration with Dr. Mircea Malitza of the University of Bucharest. The conference is being jointly organized with the International Political Science Association and will be held this coming summer in Romania.

Various aspects of the energy crisis are the subjects of another major part of the Center's program. The Japanese government has created at MIT the Japanese Endowment for International Energy Policy Studies. Work under this endowment will be conducted jointly by the Center and the Program in International Energy Studies of the MIT Energy Laboratory. The major participants to date are Dr. Skolnikoff, Professor Henry Jacoby of the Energy Laboratory and the Sloan School of Management, Dr. Tom Neff of the Energy Laboratory, Dr. Lester of the Department of Nuclear Engineering, and Dr. Richard Samuels of the Department of Political Science.

Issues concerning the relationship between trade in nuclear energy technology and nuclear proliferation have been the subjects of a series of bilateral conferences over the past several years, involving groups of policymakers, industrialists, and academics from the United States and such countries as Germany and Japan. In June, a third US-Japanese meeting was held in Tokyo to explore different perspectives. These sessions have proved highly valuable in facilitating a fuller exchange of views on this crucial topic than would be possible in more formal or official settings. This series will be continued and, it is hoped, expanded to other countries. The latest Japanese workshop was funded by the Rockefeller Foundation.

Professor Joel Yellin, School of Humanities; Professor Paul Joskow, Department of Economics; and Dr. Jacoby completed a study on several international and comparative issues relating to the nuclear energy industry. The project focused on three areas: the nuclear fuel cycle, nuclear reactor safety, and the economics of nuclear power production. The Ford Foundation supported this undertaking.

International questions relating to the environment have engaged several Center researchers over the past year in a project directed by Drs. Skolnikoff and Rathjens. Dr. Howard Margolis of the Center has completed a manuscript for a book, to be published by Cambridge University Press, exploring what governs altruistic behavior. The study draws on public choice literature and extends this important body of social theory to the issue of how individuals decide to allocate a portion of their resources to the public good.

A second book emerging from this area of study is a volume co-edited by Dr. Skolnikoff, Professor Gerald Holton (Harvard University and the MIT Program in Science, Technology, and Society), Professor Leo Marx (Program in Science, Technology, and Society), and Professor Saul Friedlander (Hebrew University of Jerusalem). The book will look at the visions of "the end" that have preoccupied Western thought; it grew out of a seminar on the same theme organized by Dr. Friedlander at MIT several years ago. The book will be published by Holmes & Meier.

The international environment project supported 10 graduate students, including eight from developing countries. The program also undertook several smaller studies -- including a critique of the work of the United Nations Environmental Program (UNEP), a study of the potential environmental effects of macroengineering projects, an analysis of international rules concerning ocean oil pollution, and a study of the social impacts of climate change. Dr. Margolis is completing a study on the issue of damage to the ozone layer; the focus will be on how the international community dealt with this issue, on which no single interpretation of the scientific evidence is universally accepted, while the potential hazards are enormous. The Center's work on these international environmental questions has been supported by the Rockefeller Foundation, the Andrew W. Mellon Foundation, and the UNEP.

Problems with respect to the environment present many examples of the more general question of risk assessment. The Center, jointly with the MIT Program in Science, Technology, and Society, sponsored a series of faculty seminars at which members of the faculties of MIT and other area universities presented the current state of scientific evidence on risks such as the CO₂ "greenhouse effect," ozone depletion, environmental cancer agents, and nitrates in food. The purpose has been to explore the policy implications that flow from the presently known facts. Dr. Lawrence McCray, at the Center for International Studies on leave from the Environmental Protection Agency (EPA), organized the program and also has drawn up a census of the many individuals at MIT whose work concerns some aspect of risk assessment. Dr. Skolnikoff, Dr. Greenwood, and Professor Donald Blackmer, School of Humanities, have directed the seminars and are taking the lead in further developing the program. Plans are at present being formulated to continue this effort, hopefully to include a working faculty seminar on one or more specific risk assessment issues. The seminars to date have been supported by the Alfred P. Sloan Foundation.

The Center also has been significantly involved in the planning of a joint MIT-Harvard University program relating to the effects of toxic chemicals on human health and the environment. Participating in the planning have been Walter Rosenblith, MIT Provost, and members of the faculties and research staffs from toxicology, the atmospheric sciences, as well as various fields of medicine, chemistry, biology, chemical engineering, public health, biostatistics, civil and mechanical engineering, nutrition, political science, economics, and management. The Center's specific contribution to this effort will be to explore the international policy aspects of the joint program's work. A grant has been obtained for this purpose from the Andrew W. Mellon Foundation. Work has begun on comparative toxic chemicals policy by Professor Jerome Rothenberg, Department of Economics. Additional studies are planned on the development of a model treating choices by political actors as a result of conflicting pressures and incentives coming, on the one hand, from technical analysis and, on the other, from interests of various groups in the society. This work will be carried out by Dr. Margolis. Professor Ann Friedlaender and Dr. Subodh Mathur, both of the Departments of Mechanical Engineering and of Economics, will be studying the ways in which toxic chemicals issues enter into international trade decisions.

Finally in a closely related area, Professor Greenwood has developed a study, for which funding is being sought, on how regulatory agencies use scientific and technological information and personnel in performing their regulatory functions. The work will focus on the Environmental Protection Agency and the Occupational Health and Safety Administration.

The field of communication has remained a major focus of the Center program. Dr. Ithiel Pool, Department of Political Science, is the director of this effort, which is coordinated with activities in the Center for Advanced Engineering Study, the Center for Policy Alternatives, the Laboratory for Computer Science, and the Laboratory for Information and Decision Systems. Core support for the program has come from the Markle Foundation, Citibank, the Hughes Aircraft Corporation, American Telephone and Telegraph Company, and International Business Machines Corporation (IBM). A major focus of effort over the past year has been creating a faculty Career Development Chair in Communications Policy and the development of a graduate course in this field by the Departments of Electrical Engineering and Computer Science and Political Science.

In addition, the Center's part of the program has undertaken several specific studies. Dr. Pool, in collaboration with Professor Hiroshi Inne of Tokyo University and Dr. K. Yukimiro of the Research Institute of Telecommunication and Economics in Tokyo, is developing a census of communication flows. The study will provide important social indicators and, by comparing the

two countries, will enable culture-specific trends to be distinguished from those that are more basic. This study is supported by the Markle Foundation and by the Japanese Society for the Promotion of Science. The Markle Foundation also is supporting a study under Dr. Pool's direction of the significance of the export market for American television productions. The Organization for Economic Cooperation and Development (OECD) has supported a study by Dr. Pool and Dr. Richard Solomon of the Center for Policy Alternatives on the effects on European communications of efforts to regulate the flow of information across borders.

Dr. Pool is at present completing plans for a major new inquiry into ways in which communications technology could be mobilized to reduce petroleum use in the United States in the event of a future supply crisis. Funds are being sought to undertake this very significant inquiry.

The area of food and nutrition has continued to be the focus of a program run jointly by the Center and the Department of Nutrition and Food Science, with Dr. Skolnikoff of the Center and Professor Nevin Scrimshaw of the Department being primarily responsible for the effort. Two major international conferences were held during the past year. In November a conference on the interface between nutrition policy and its implementation brought together scholars and practitioners from 14 foreign countries, international institutions, universities, and foundations to discuss and compare experience in developing and implementing nutrition policy. This conference was arranged by Dr. Mitchel Wallerstein, Departments of Nutrition and Food Science and Political Science, and involved Dr. Ranjit Chandra, Dr. George Ropes, Professor Barbara Underwood, and Professor Vernon Young, all of the Department of Nutrition and Food Science; Professor Richard Eckaus, Department of Economics; Professor Taylor, Departments of Economics and of Nutrition and Food Science; and Dr. Ernst R. Pariser, Sea Grant Program; along with Drs. Skolnikoff and Scrimshaw. Support for the conference came from the Rockefeller Foundation and the United Nations University.

A smaller working conference, sponsored by the United Nations University, was held in June to assess current levels of understanding on the matter of protein-calorie malnutrition. Drs. Scrimshaw, Underwood, Young, and Taylor were the MIT faculty members principally involved.

Dr. Taylor, in collaboration with Dr. Graciela Chichelinsky of Columbia University, is undertaking a study of the food system, inflation, and international investment as they impact poor countries' income distribution and growth. The research is supported by the United Nations Institute for Training and Research.

In addition to this program of meetings and research, the Center contributes to MIT's work on development matters by serving as coordinator for participation in the Title XII Program, an effort to involve land grant colleges more effectively in US government development and technical assistance programs abroad. Also the Center is sponsoring, together with the Center for International Affairs at Harvard University, a group of faculty, students, and research staff concerned with the role of women in development. The Center has continued to cosponsor, with Harvard's Center for International Affairs, the Joint Seminar on Political Development; and with the Center on Development Studies at Boston University the Faculty Seminar on South Asia. Both are open to all area scholars.

During the past year, Professor Lucian Pye, Department of Political Science, traveled in Asia on the first stage of a new comparative look at how Asian societies and institutions respond to Western ideas and technology. He is studying the responses to the railway and communications systems, to the Western concepts of education, and to the growth of government institutions. Dr. Pye's work is supported by the Rockefeller Brothers Fund. He hopes to enlist the collaboration of Asian scholars in the next stages of the study.

Migration of peoples, within countries and across borders, has continued to be a major research interest of the Center. In a program that involves Professors Myron Weiner, Nazli Choucri (both of the Department of Political Science), Michael Piore (Department of Economics), and Dr. Rosemarie Rogers (Center for International Studies), the Center has explored such varied issues as the tensions that have arisen in India as peoples of differing language groups migrate within the country, the effects on political attitudes of the experiences of migrant labor in Europe, and the effects of migrant labor on US wage levels. A major NSF-supported study by Dr. Choucri during the year looked at the migration of skilled labor among Arab countries in the Middle East.

In a separate program area, Professors Piore and Charles Sabel (Program in Science, Technology, and Society) are making a comparative study of the relationship between labor management relations and the general performance of the economy. The German Marshall Fund of the US is supplying funds for this research.

The Program in International Business (PIB), a Center effort sponsored by a number of industrial concerns -- John Deere, Caterpillar Tractor, Pfizer, Morgan Guaranty Trust, IBM, IBM World Trade, Merck, Unilever, Universal Oil, Nestle, St. Gobain -- has conducted two programs during the past year. Professor Steven Kobrin, School of Management, has examined how multinational businesses reach judgments about political risks -- that is, where data are obtained, where in the firm decisions are made, and the models used to forecast futures. Professor Daniel Holland, School of Management, has continued to direct an international inquiry on how rate of return on capital should be measured; a second international conference on this question is planned in London for the summer of 1980. The over-all PIB program is directed by Professor Richard Robinson, School of Management.

Several other smaller programs continued through the past year. Professor William Griffith, Department of Political Science, with funding from the Earhart Foundation, has examined radical and Communist movements outside the Soviet Union and Warsaw Pact and also has studied closely relations between Eastern and Western Europe. Professor Robert Rotberg, Department of Political Science, has written extensively on developments in southern Africa. Professor Willard Johnson, Department of Political Science, has studied African development, with particular emphasis on the relationship between African and Arab Islam. A grant from the Albert Kunstadter Family Foundation is supporting work under Dr. Rotberg's direction on a biography of the late Henry Chipembere, a leader in the independence movement in Malawi.

In addition to conducting research under its own auspices, the Center maintains close working relationships with other major projects and programs at MIT that have closely related interests. Some of these have already been mentioned. Prominent among them are: the study of the future of the automobile, directed by Professor Alan Altshuler of the Department of Political Science and Professor Dan Roos, Center for Transportation Studies; the Technology Adaptation Program, directed by Professor Fred Moavenzadeh, Department of Civil Engineering, and Professor Choucri; the Energy Laboratory, directed by Professor David White, Department of Electrical Engineering and Computer Science; and the Program in Science, Technology, and Society directed by Dean Blackmer. The Center also collaborates closely with the Center for Science and International Affairs and the Center for International Affairs at Harvard University.

As in past years, the Center has welcomed a number of visiting scholars whose presence enriches our outlook. During the past year, these have included Miriam Campanella, University of Turin, Italy; Hubert Hinds, United States Air Force; Brian Martin, United Nations Environmental Program; Liborio Mattina, University of Catania, Italy; Gautam Sen, University of Illinois; Nicholas Smith, North Carolina State University; and Anselm Yaron, Israeli Ministry of Defense. The Center also has continued to publish its monograph series and to sponsor an extensive program of seminars. In addition to some seminar series with themes -- arms control, South Asia, African studies, migration, communications, environment, risk assessment -- others have addressed more general international topics.

EUGENE B. SKOLNIKOFF

Center for Materials Research in Archaeology and Ethnology

The Center for Materials Research in Archaeology and Ethnology (CMRAE) completed its third year of activities supported primarily by several continuing grants from the National Endowment for the Humanities (NEH).

EDUCATION PROGRAM

The Center offered two graduate seminar-laboratory subjects in which 22 students were enrolled from CMRAE's seven-member institutions. Professor Heather Lechtman (MIT) taught the subject Materials in Ancient Societies: Metals in the fall semester, and Professor George Cowgill (Brandeis University) taught a full-year subject, Mathematics and Computers in Archaeological Data Analysis. Both classes made extensive use of the Center's Graduate Laboratory in Building 20. The Laboratory is outfitted with the basic equipment necessary to investigate the major classes of materials normally encountered in archaeological and art historical research: ceramics, metal, rock, faunal and floral remains.

Several important additions were made to the Graduate Laboratory during the course of the year. CMRAE received a grant from the Samuel H. Kress Foundation, New York for the purchase of several light microscopes for metallurgical or biological studies. These were used by students in the Metals class to conduct metallographic examinations of specimens from artifacts obtained during controlled excavations.

Funds provided by Dean Harold Hanham (School of Humanities and Social Science) and Weston J. Burner (Director, Information Processing Services) enabled us to outfit the Laboratory during the year with two computer terminals and to cover the costs of student computing time. These facilities formed the backbone of the Computers and Archaeology subject.

Given the extent to which the terminals were used and the planning of next year's curriculum to include computer analysis, the Office of the Provost provided the Center with funds to purchase one of the terminals which will be permanently located in the Graduate Laboratory.

During the spring semester, four members of the faculty drew up final plans for the subject to be offered in 1980-81, Biological Materials in Prehistory. As a full-year course, the subject will be taught by Professor Lawrence Kaplan (University of Massachusetts, Boston), Professor Gerald Kelso (Boston University), Richard Meadow (Harvard University), and Professor Wilma Wetterstrom (MIT).

CMRAE was formally established in 1977, but its education program began in 1975. To date, 95 graduate and senior undergraduate students from the Center's seven-member institutions have enrolled in our graduate courses.

RESEARCH PROGRAM

The main thrust of the Center's research program for the past year was the establishment of reference collections of certain classes of archaeological materials that can be used for research purposes by CMRAE students and faculty, as well as by scholars from other institutions. This work was facilitated by a planning grant from the Research Division of NEH which terminated on June 30, 1980.

Our most interesting and important activities in the area of reference collections centered about the establishment of a Phytolith Laboratory at the University of Massachusetts, Boston under the direction of Professor Kaplan of the Department of Biology. Phytoliths (silica bodies or plant opals) may prove of unusual interest to archaeologists in reconstructing the vegetation-climate conditions of previous culture periods, and in identifying food plant species at archaeological sites where pollen or organic microfossil analysis is unavailable. Thus far, the CMRAE Phytolith Laboratory has processed and collected silica bodies from 60 taxa of Old World and New World grains. Research has begun on the morphological typing of individual silica bodies, chiefly through scanning electron photomicrography. Through the development of these reference collections we can already distinguish between maize and its closest wild relative, teosinte, and among types of wheat such as einkorn, emmer and bread wheat, all of which are prehistoric Old World domesticates. The Center will seek major funding in the year ahead to continue the important research of this Laboratory.

Clinical Research Center

Expansion and refining of the Center's outstanding collection of archaeological metal specimens was supervised by Professor Lechtman. One of the most significant additions to the metals reference collection is a group of 200 samples of copper-arsenic and copper-tin alloys prepared by the Center's Metallurgy Laboratory. The copper-arsenic alloys constitute a unique collection of arsenic bronzes in the United States, and study of their properties is under way at the Center. The metals reference collection currently contains approximately 1,100 catalogued specimens.

Under Professor Lechtman's direction, the Center began construction and installation of a thin section facility at the Graduate Laboratory. When complete, the facility will accommodate materials such as rock, ceramics, and bone. With the guidance of Mr. Meadow, a zooarchaeologist at Harvard University, CMRAE has begun the preparation of thin sections of faunal materials, including bone and teeth, that will form the core of a new reference collection of such sections.

The Center does not aim to establish comprehensive reference collections for archaeological use, but rather to conduct basic research into the characteristic properties of the materials we deal with so that those properties can be used in furthering other kinds of archaeological analysis. The phytolith reference project is typical of this approach.

HEATHER LECHTMAN

Clinical Research Center

The MIT Clinical Research Center (CRC) is an Institute resource established for the support and care of patients participating in research studies conducted by MIT investigators. Its aim is to facilitate and enhance research in human health and disease under conditions of optimum patient care.

The past year continued to be highly productive for the CRC. Research studies conducted at the Center involved 3,286 inpatient days and 1,094 outpatient visits under 23 different research protocols. Bed occupancy averaged 90 percent.

In July 1979 Professor Nevin S. Scrimshaw assumed the position of Program Director and the previous Director, Professor John Burke became Chairman of the Subcommittee on Medical Standards and the Executive Committee. Dr. Ranjit Chandra, Visiting Professor of Nutritional Immunology in the Department of Nutrition and Food Science became Associate Program Director in September. Marlene Thurston joined the staff as research dietitian in November and has provided additional support to the dietary unit which is responsible for the supervision and organization of the metabolic kitchen.

Research activity involving outpatient volunteers increased markedly during the past academic year. Factors contributing to this were the opening in September of the new outpatient facility which includes two treatment rooms, a waiting room, and a medical records room, and the completion of the renovations for new administrative offices, four outpatient testing rooms, and an office for graduate fellows in the Clinical Nutrition Training Program. These expanded facilities have enhanced the Center's operation significantly by attracting a number of new investigators as well as enabling established investigators to increase the number of subjects in their studies. Completion of the renovated space also enabled the CRC to convert vacated office space into a combined infusion and exercise testing room. This room was especially equipped for investigators, particularly Professor Vernon Young and Dr. Bruce Bistrian, to conduct infusion procedures as part of their research on dietary amino acid requirements and variations in metabolic function.

Studies under the direction of Professor Young have continued on the exploration of protein and amino acid metabolism in healthy adult subjects and its response to dietary factors. These studies have expanded the use of stable isotope tracers for qualifying components of whole body and organ protein metabolism. With these techniques Professor Young has discovered that the mechanisms associated with the maintenance of body homeostasis are linked to the amino acid

and protein requirements of the individual. This observation suggests that new and novel methods, based on determination of the dynamic status of amino acid metabolism, could be developed for purposes of determining the amino acid requirements of humans under varying conditions of health and in disease. A series of studies are currently under way to establish the validity of this hypothesis.

Investigators from the Department of Psychology moved into four of the outpatient testing rooms developed as part of the renovations completed in the fall. Professors Emilio Bizzi and Alan Hein have been concerned with setting up their experimental equipment and will begin testing patients sometime this year. Dr. Suzanne Corkin and her colleagues have significantly increased the number of patients participating in their protocols as a result of the expanded testing facilities. The protocols involve investigations of brain-behavior relationship with six different subject populations: 1) veterans with penetrating head injuries sustained during World War II; 2) patients who received a neurosurgical procedure, either cingulotomy or leucotomy, for the relief of chronic pain or psychiatric disease; 3) children and adults with craniopharyngiomas, tumors that invade the third ventricular region; 4) woman with Turner's syndrome, a chromosomal disorder characterized by ovarian dysgenesis, low endogenous levels of estrogens and androgens, and short stature; 5) patients with Alzheimer's disease, the most prevalent type of senile dementia; and 6) healthy elderly subjects. In trying to understand the brain mechanisms that are affected in the six different groups, they have used quantitative behavioral tests to sample cognitive, sensory, and sensorimotor functions, as well as motivation and affect. They have then related the data thus obtained to the concomitant morphological or chemical alterations in the brain.

In October 1979 Professor Padmakar Lele from the Department of Mechanical Engineering initiated the clinical outpatient phase of his study of local ultrasonic hyperthermia for cancer therapy. The CRC provided the necessary space for the experimental equipment required which enabled Dr. Lele and his colleagues to treat cancer patients from the Massachusetts General Hospital and the Sidney Farber Cancer Institute.

Physicians participating in the human nutrition and metabolism training program offered by the Department of Nutrition and Food Science, in collaboration with four area hospitals, utilized CRC facilities to initiate new research protocols and to participate in ongoing projects supervised by senior investigators and faculty. During the past year 14 physicians, representing the specialties of internal medicine, surgery, and pediatrics, were active in the program. Their research interests include adolescent obesity, exercise and diet, total parenteral nutrition for premature infants, and the effect of early nutrition on gastrointestinal development. Following their training, physicians in this program have entered clinical departments of medical schools or hospitals and have been responsible for developing effective programs in training, research, and patient care.

The CRC also provided research support to visiting physicians and scientists training in nutritional research as fellows in the World Hunger Program of the United Nations University (UNU). Over the past year UNU fellows from the Middle East, South America, and the People's Republic of China were actively involved in studies at the CRC.

Dr. William Dietz, Assistant Program Director and a program trainee, submitted an application to the National Institutes of Health (for the position of Clinical Associate Physician at the CRC) and received a two-year award beginning in July 1980 that will enable him to continue and expand his research efforts at the Institute. His studies have shown that hepatic glucose production in obese adolescents is comparable to that of the non-obese and is readily suppressible by the infusion of exogenous glucose. His preliminary results indicated that protein plus carbohydrate appear to improve nitrogen balance when compared to an isocaloric, isonitrogenous, carbohydrate-free diet. Increased lean body mass determined by H_2O^{18} is an important variable that must be controlled in the study of dietary therapy in obese adolescents.

The CRC sponsored a weekly seminar for students and staff. Investigators conducting studies at the Center or at affiliated institutions were invited to discuss their current research projects or to present information on a subject relating to human research. These seminars were attended by individuals representing a wide variety of academic and research interests from MIT and nearby institutions. Members of the CRC research and investigator staffs also offered courses to the MIT community as part of the Independent Activities Period. These included instruction in grounding techniques for medical and laboratory equipment, a seminar on space medicine, and a seminar on exercise and weight reduction.

NEVIN S. SCRIMSHAW

Committee on the Visual Arts

COMMITTEE ACTION

The Committee on the Visual Arts (CVA), a presidentially appointed advisory body composed of faculty, administration, and student members, coordinates an active, non-curricular visual arts program for the MIT community and general public. Founded by former President Howard Johnson shortly after his inauguration in 1966, the Committee was an outgrowth of a widespread concern for the Institute's visual environment and for the role of the visual arts in scientific and technological education. C.P. Snow had identified a chasm existing between what he termed "the two cultures" of the scientific and humanistic worlds. At MIT the importance of visual literacy had been earlier acknowledged as crucial to the balanced education of both scientist and engineer: a 1957 report of an ad hoc Committee for the Study of the Visual Arts advocated an art program which would "cultivate a feeling for intuitive qualities which cannot be strictly advanced by logic, yet upon which the modern scientist finds himself increasingly dependent."

The CVA sets the policy and procedural guidelines governing the organization of the exhibition and publication program, the acquisition and curatorial care of a growing Permanent Collection and of two student loan collections, and the sponsorship of a variety of educational activities. Its programs are designed not only to supplement the educational opportunities within the Institute community but also, through associations with local, state, Federal, and European agencies and councils, to address regional and international concerns. The Committee's actions are coordinated with those of its professional staff which is responsible for the planning and administration of the programs.

The CVA focused successfully on defining conservation priorities and on securing funds for the care of art works in the Institute's Permanent Collection. In doing so, the Committee reiterated the Institute's commitment to a publicly sited Permanent Collection rather than to one sequestered in a museum environment; however, it also acknowledged that such a collection was subject to unusual physical stress and required a well-defined conservation program. The Committee was reluctant to accept major large-scale paintings or sculptures without first determining a secure site and developing educational programs to assure a favorable reception in the MIT community.

The programmatic, spatial, and budgetary proposals relating to the Arts and Media Technology Facility continued to occupy the Committee.

Among other important issues discussed were ways of expanding the student loan collections and defining appropriate acquisitions for them. Letters soliciting support for this program were drafted to members of the MIT Council for the Arts by Ida Rubin, chairperson of the Council's Acquisitions Committee, and to alumni who, as students, had received prints from the collections by Leigh Passman, undergraduate member of the Committee.

A new Arts Advisory Committee which includes Council members Agnes Mongan, James Plaut, and Agnes Saalfield, and CVA members David Friedman, Heather Lechtman, Deborah Hoover, and Boris Magasanik met with CVA staff several times during the academic year. Discussions focused on a variety of concerns including the character and direction of the Institute's art collections, the definition of a conservation program, and the proposed programmatic plans for the new facility. The first major recommendation was to curtail the MIT acquisitions program until conservation funds were secured. The modest funds received will allow the Arts Advisory Committee to clarify the aesthetic needs of the Permanent Collection.

PERMANENT COLLECTION

The MIT Collections which include the Permanent Collection and two Student Loan Collections consist of over 1,000 works of art. The primary focus is on contemporary sculpture, painting, and works on paper.

Acquisitions

Numerous works were acquired through either gift or purchase during the 1978-79 academic year; among these works were M.C. Escher's lithograph, *Waterfall* (1961), a gift of alumnus Richard W. Ihrie; *Six Aquatints* (1975) by Robert Ryman, a gift of the Albert and Vera List Family Collection; and Grace Hartigan's work on paper, *H.K. Boyce* (1962), a gift of Max Wasserman in honor of the Council for the Arts at MIT.

In addition to gifts, numerous important works were loaned to the Institute, including Michael Heizer's sculpture *Guennette*, loaned by the Metropolitan Museum of Art, New York. The loan of six major sculptures by Jacques Lipchitz was renewed by Mrs. Yulla Lipchitz for an additional five years.

New Installations and Sitings

Two major sculptures were added to the Permanent Collection in the past year. *Guennette* by Mr. Heizer, on extended loan from the Metropolitan Museum of Art, was installed and dedicated in Lowell Court on May 1. An untitled corten steel sculpture by Ellsworth Kelly, on indefinite extended loan, was sited in late May in the Hayden Memorial Library Building. The large-scale wall relief by John Willenbecher was relocated to the third floor mezzanine of Building 7.

A large contemporary scroll painting by Liu Haisu was presented to MIT by Professor Ching T. Yang from the People's Republic of China. The painting was hung temporarily in the President's House. The large painting *Hochman* by Gary Bower, on extended loan, was hung in the fifth floor lounge of the Landau Building for the Chemical Engineering Department. As in the past, numerous paintings and works on paper were sited in public spaces, conference rooms, and offices.

Loans to Other Institutions

The Neue Gesellschaft für bildende Kunst of Berlin received approval for the loan of *Catalytic Crackers* by Thomas Hart Benton for an exhibition to open in November 1980 entitled "American Realism 1920-1940." Because the painting required extensive conservation treatments before traveling, the Berlin host consented to share the expenses for restoration.

Conservation

A grant for a conservation survey of the MIT Permanent Collection and the student loan collections was awarded by the Institute of Museum Services, US Department of Education, which offers operating and program support to the nation's museums. The grant provided for the inspection and evaluation of the collections by the staff of the Center for Conservation and Technical Studies of the Fogg Museum. Evaluations include current condition reports for each work, specifications for conservation treatment, and estimated costs for such treatments. The survey allowed the Committee to set priorities for the treatment of works and formed the foundation for a conservation program. The Registrar and Gallery Manager received training in basic conservation procedures and recommendations for siting and storage practices during the survey, the first to be undertaken at MIT.

A program for conservation of the outdoor sculpture collection was coordinated with MIT Physical Plant. In October the *Model for the Big Sail* by Alexander Calder was sandblasted and repainted with primer and finishing coats of paint.

Special funds were secured to properly mat 52 small and three large working drawings for the MIT *Belltower* by Theodore Roszak. The drawings, forming the nucleus of the Reference Collection which traces the creative process, are now available for study by students and scholars.

Vandalism

A painting by Jacqueth Hutchison, *Adonis Blue Goes Mauve*, hung in the third floor lounge of the Landau Building, was slashed. The work had been sited for several years without serious prior damage. Following a moratorium begun last year as a temporary solution to security concerns, no new paintings were sited in unmonitored public spaces.

One-Percent for Art Projects

In the past, One-Percent funds were allocated routinely for a new facility; however, policy regarding the allowance for renovated buildings was less clear. This year, the Director of Exhibitions worked with Provost Walter Rosenblith, Planning Officer O. Robert Simha, and Campus Architect Harry Portnoy to formulate such a policy. It was agreed that an art allowance would be included in all renovation budgets over \$25,000.

Two projects involving MIT's One-Percent for Art allowance were discussed in great depth. The Committee explored the work of 10 artists before asking Gary Wiley, a sculptor, and former Center for Advanced Visual Studies fellow Peter Campus, video artist and photographer, to prepare proposals for the Animal Care Facility. A final review of the completed proposals will take place in early autumn.

Working with architects (I.M. Pei & Partners), the client team, and the MIT Council for the Arts, the Committee invited six artists to collaborate with the architects on the design of various elements of the proposed Arts and Media Technology Facility and landscape. The collaboration, supported by the One-Percent for Art allowance and matched by National Endowment for the Arts funds, promises to expand traditional definitions of public art, whereby works were placed on pedestals or walls. Striving to integrate utilitarian functions with aesthetic aspirations, discussions were begun with Richard Fleischner, Dan Flavin, James Turrell, Scott Burton, Kenneth Noland, and Alan Shields.

The major portion of funds allocated from the renovation of the Alumni Center were used to purchase a cast bronze sculpture by Michael Steiner. Monies remaining from the fund will be used to purchase limited edition prints for the Alumni offices.

EDUCATIONAL PROGRAMS

The CVA strives to integrate its education and exhibition programs. The intention is to broaden the public's awareness of the artist's creative methods and professional concerns as well as to increase understanding of the historical roots of and salient issues in contemporary art. The program has generated much interest from local institutions, and the staff has assisted Northeastern, Tufts, and Suffolk universities in developing their own programs. The staff also helped the MIT student directors of the Burton House Gallery to define and implement their program.

List and Stratton Student Loan Programs

An exhibition of framed prints and posters from the Catherine N. Stratton Collection of Graphic Art and the List Student Loan Program was hosted in Hayden Gallery from September 4-14. Thirty-four works were added to this year's program. A total of 152 framed works was offered to individual students, and five large framed works to organized student groups. Over 750 individual students and more than 25 student groups entered the lottery.

Provost

In the past year an endowment from the James A. Taylor Family Foundation was given in support of the student loan programs. Plans to supplement this endowment and to increase the number of available prints are being developed.

Artifacts

Artifacts, an informal discussion and activities group, met monthly from November through May. The group viewed exhibitions of contemporary art in local galleries and museums, toured the Print Conservation Department of the Museum of Fine Arts, and discussed the Hayden Gallery "Arts on the Line" and "Bochner/Serra" exhibitions with the Assistant Curator. The group also examined issues of siting, acquisition, and maintenance of the Permanent Collection during an introductory slide presentation at its first meeting and on a walking tour in May. From 15 to 25 undergraduates, graduate students, and MIT staff members attended each meeting. A tentative selection of works on paper to be purchased by the group for one of the student loan collections was made.

Cindy Carter, a work-study student and Artifacts member, initiated and organized a series of performances of student work including poetry, music, and video presentations which the Committee sponsored.

Artist-in-Residency Project

In conjunction with the retrospective Hayden Gallery exhibition of Agnes Denes' work, an artist-in-residency project was sponsored during Independent Activities Period from January 7-15. The artist used facilities of the MIT Creative Photography Laboratory to produce photographs for a new project. As new work was printed, it was included in the gallery exhibition, enabling the general public to chart the project's development. Assisted by an MIT graduate student and by a professional photographer, the artist explored a number of possible formats for the new project.

Ms. Denes gave a public slide lecture followed by an open discussion and an informal talk in Hayden Gallery. The residency also provided an opportunity for discussions with faculty and staff from various Institute departments including the Visible Language Workshop, the Center for Advanced Visual Studies, the Architecture Machine Group, the Artificial Intelligence Laboratory, as well as with individual faculty members including Professor Harold Edgerton. In addition, contacts were developed with faculty and staff from the Harvard Center for Astrophysics.

Tours and Gallery Talks

The staff offered numerous gallery talks, slide presentations, and walking tours of the Permanent Collection this year. Tours were given to individuals from the Dallas Museum of Art, the South Shore Art Society, and the MIT Wives group. The two gallery talks on the "Narrative Impulse" exhibition were supplemented by one given by Michael Mazur, guest curator, to the Museum of Fine Arts Print Club. Talks on "Corners" were attended by classes from the Museum School and from Emerson College. Gallery talks on "Arts on the Line" were given to the MIT Department of Transportation Studies, a group of urban planners and designers, a group of architects for the new Southwest Corridor development for the MBTA, several groups of MBTA officials, a group of high school design students from Burlington, Massachusetts, and to over 150 children from public schools in Cambridge and Somerville.

The Walking Tour

Funding from the National Endowment for the Arts was continued through this year for the Walking Tour Catalogue, a guide to the Institute's visual environment. Its purpose is to make information about MIT's art and architecture more accessible to visitors and to community members.

Internships and Volunteers

A part-time volunteer continued to assist the Registrar in preparing background information on artists in the Permanent Collection and on updating registrarial records for the Collection. While no interns were accepted in the past year, two interns were accepted for next year. One work-study student assisted the Fine Arts Registrar during summer 1979.

Video and Slide Resources

Original videotape interviews with the artists and slide presentations became an important educational component of each Hayden Gallery exhibition by enhancing the viewer's understanding of the artists' sensibilities and intentions.

All videotapes produced during the year played continuously in the gallery during each exhibition, and are housed in Rotch Visual Collections to encourage regular reference use. Videotapes will be played at intervals over both MIT and Harvard cable TV stations.

For the "Narrative Impulse" exhibition, guest curator Michael Mazur conducted interviews with the three other artists featured in the exhibition. For "Agnes Denes: 1968-1980," Gary Garrels, curator of the exhibition, conducted an interview with the artist in Hayden Gallery.

"Conversations on Public Art," produced for the "Arts on the Line" exhibition was a provocative examination of the salient issues involved in siting public art. Michael Pittas, director of the National Endowment for the Arts' Design Arts Program; Grover Mouton, artist, architect, and the coordinator of a public arts project in New Orleans; and Grayce Stead, a resident of North Cambridge and a future user of the MBTA stations, gave an informal critique of each of the 20 artist's proposals for the new stations. Their dialogue was augmented by footage of current MBTA construction sites and existing stations. The tape will be distributed to transportation studies groups, urban planners and architects, community arts agencies, and artists by the Cambridge Arts Council in collaboration with the CVA.

A videotape was produced to document the "May Day" celebration and dedication of Mr. Heizer's sculpture *Guennette*. Landscape architects Martha Schwartz and Peter Walker designed an edible sculpture garden grid of 40,000 Necco candy wafers and 144 pastel-painted tires. The garden paid homage to the whimsy of spring and mirrored the formality of Killian Court, the sculpture's site. Included in the tape are references to the Beaux Arts gardens which Ms. Schwartz and Mr. Walker used as their point of departure. The tape will be used by Walker's landscape architecture and design classes at Harvard University, and for an art history seminar at MIT.

The slide presentation created for "Aldo Rossi: Between Inventory and Memory" provided a visual chronology of the architect's completed works and included references to artists and architects who influenced Rossi.

Videotapes were directed by Bernice Schneider, a special student at the MIT Film/Video section, using resources of the Film Video section and of Educational Video Resources.

Teacher Training Workshop Pilot Program

Teacher training workshops for 10 Somerville public school teachers were held in conjunction with "Arts on the Line," an exhibition which offered a unique opportunity for the Committee to strengthen its associations with the local community. After the two-hour participatory workshop, each teacher conducted tours of the exhibition for their students and prepared follow-up activities in the school.

Because of the success of this small pilot program, the Committee intends to continue these workshops in order to expose young students and their teachers to contemporary art.

Publications and Public Information

In support of the Hayden Gallery and Hayden Corridor Gallery exhibitions, various educational publications were produced in order to heighten the viewer's appreciation and understanding. Extensive explanatory wall texts were posted prominently for each of the 13 exhibitions. Catalogues were produced and distributed nationwide for "Corners," "Narrative Impulse," "Arts on the Line," and "Bochner/Serra." Brochures were produced for "Agnes Denes: 1968-1980," "Theodore Roszak: Drawings for Constructions 1931-1945," and "Aldo Rossi: Between Inventory and Memory."

Press releases for exhibitions and activities were prepared by the CVA staff as publicity and educational support.

Posters designed by Jacqueline Casey, Director of MIT's Design Services, for Hayden Gallery Exhibition and postcard announcements for Hayden Corridor Gallery were distributed throughout MIT and to over 3,400 on the mailing list. The "Arts on the Line" poster also was distributed by the MBTA and displayed in all Cambridge and Somerville public transportation vehicles.

A major press conference was held in Hayden Gallery by Joan Mondale, wife of the Vice President, and Theodore Lutz, Assistant Secretary of the US Department of Transportation. Also in attendance were Mrs. Edward King, wife of the Governor, and Robert Foster, then Chairman of the Massachusetts Bay Transportation Authority. Over 100 representatives from local and national TV and radio networks attended.

NBC TV filmed the making of the Necco Garden for the May Day celebration held in Killian Court, and aired the tape on the 5:30 news on May 1, 1980.

Descriptive highlights and photographs of the MIT Permanent Collection as well as a summary of the Committee's programs will be included for the first time in the forthcoming revised edition of *Art Museums of New England* prepared for David Godine Press. Highlights of the MIT Permanent Collection and/or information on the program also will appear in a number of forthcoming reference works.

Works in the outdoor sculpture collection were featured in articles in the past year in *Horizon* and *Portfolio* magazines. An additional article in *Portfolio* examining the status of the visual arts in Boston and New England noted the special contribution of the Hayden Gallery to the vitality of the regional art scene.

As in years past, reviews of Hayden Gallery exhibitions were included regularly in the local and national press as well as in campus publications.

EXHIBITIONS PROGRAM

The 1979-80 exhibitions program reflected the ongoing commitment to innovative and experimental activity in painting, photography, sculpture, and architecture as well as to areas which bridge traditional distinctions between media. Hayden Gallery exhibitions attempt to identify artists of unusual promise as well as those of established reputation. Artists are encouraged to use MIT's facilities in order to experiment in an unfamiliar or promising idiom. Attendance surpassed 20,000 visitors, continuing an encouraging pattern of expansion. The Hayden Gallery is open seven days a week from 10 am to 4 pm and on Wednesday evenings from 6 to 9 pm. Each exhibition opens with a preview; the participating artists usually attend.

Schedule for 1979-80

Jacqueline Casey: Hayden Gallery Poster Designs 1966-1979, Hayden Corridor Gallery, August 27 - September 23, 1979. Ms. Casey, Director of MIT Design Services and nationally known graphic designer, showed 14 years of Hayden Gallery exhibition posters, many of which have received awards from noteworthy graphics and communications organizations.

List and Stratton Student Loan Collection, Hayden Gallery, September 4-14, 1979. 152 works on paper from the Catherine N. Stratton Collection of Graphic Art established in 1966 and from the List Student Loan Collection begun in 1977 were shown. Constituting a broad survey of trends in recent American printmaking, the exhibition offered students the occasion to compare the different technical and aesthetic issues of the various graphic media. This popular lending program is designed not only to enhance individual living quarters, but to encourage habits of critical vision and a lifelong involvement with the visual arts.

Corners, Hayden Gallery, September 29-November 4, 1979. Recent explorations into site, process, and the relationship between real and illusory space have found the corner a charged and fruitful locus. Installation pieces by Don Dudley, James Ford, and Patrick Ireland designed specifically for this exhibition, together with permanently configured works by Richard Artschwager, Jennifer Bartlett, Anthony Caro, Bryan Hunt, Marilyn Lenkowsky, and John Newman illustrated a variety of painterly and sculptural approaches toward the corner. A 24-page illustrated catalogue was published.

Jim Pomeroy, Hayden Corridor Gallery, September 27-November 4, 1979. This exhibition consisted of stereo photographs from two extended series. By using the early 19th century technique of stereoscopic illusion, this San Francisco artist investigated perspective and its cultural implications. An evening performance of works which included unorthodox, handbuilt musical instruments further demonstrated the artist's idiosyncratic involvement with technology.

The Narrative Impulse, Hayden Gallery, November 17-December 23, 1979. A revived interest in storytelling in recent art was examined through paintings, pastels, and monotypes by Irving Petlin, Robert Birmelin, Mary Frank, and the nationally known Cambridge painter, Michael Mazur. As curator of the exhibition, Mr. Mazur was provided with a forum in which to articulate his sense of history and his conception of the recent trend toward representation.

Theodore Roszak: 1930-1955, Hayden Corridor Gallery, November 17-December 31, 1979. Drawings and models for sculptural projects spanning a 20-year period included the sculptor's preparatory sketches, maquettes and castings for the Belltower atop MIT's 1955 Saarinen Chapel. The exhibition was guest curated by Lois Fichner-Rathus, a doctoral candidate in the History, Theory, and Criticism program at MIT.

Agnes Denes: 1969-1980, Hayden Gallery and Hayden Corridor Gallery, January 7-26, 1980. A retrospective exhibition, consisting of drawings, prints, photographs, and documentation from many of Ms. Denes' projects, was held in conjunction with an artist-in-residency program which was funded by the National Endowment for the Arts. The artist used the structures and content of science, mathematics, and philosophy to create a varied body of visual images. Though well-known throughout the United States and in Europe, this was the artist's first exposure in New England.

Arts on the Line: Art for Public Transit Spaces, Hayden Gallery and Hayden Corridor Gallery, February 9-March 16, 1980. The exhibition consisted of proposals by 20 artists, both locally and nationally prominent, for artwork to be installed eventually in the four new subway stations of the MBTA Red Line Northwest Extension. The exhibition was arranged in collaboration with the Cambridge Arts Council.

Richard Serra and Mel Bochner, Hayden Gallery, April 5-May 11, 1980. This exhibition supported in part by the National Endowment for the Arts, highlighted the parallel development of two influential artists who, despite divergent styles, share a number of crucial concerns and procedures. While both have exhibited widely in Europe and the United States, this was their first major exposure in Boston. Pivotal works by each artist were featured; each created a work specifically for this exhibition. Early works that played an important role in defining the Process and Conceptual Art movements were included. The catalogue was designed by the two artists in collaboration with MIT's Design Services.

Andrew Tavarelli: Recent Pastel Fans, Hayden Corridor Gallery, April 5-May 11, 1980. More than 20 recent pastel drawings by the Boston and New York-based painter were shown, many of them for the first time. All of the drawings refer to or incorporate the shape of an unfolded fan, a structure which derives from the artist's love of Japanese art and from his interest in serial photography and composite imagery.

Between Inventory and Memory: The Architecture of Aldo Rossi, Hayden Gallery, May 23-June 22, 1980. Some 60 models, drawings, blueprints and photographs of both theoretical and built work introduce the work of this Italian architect to the Boston area. The exhibition thoroughly documented Rossi's prize-winning design for the Modena Cemetery, as well as numerous other projects for schools, residences, and civic monuments. The exhibition was organized in cooperation with the Max Protetch Gallery and the Institute for Architecture and Urban Studies In New York.

Gretchen Garner's Catalogue: An Art History of Ephemera, Hayden Corridor Gallery, May 23-June 29, 1980. This first East Coast showing of the work of the Chicago photographer consisted of a number of "pages," each composed of eight equal photographs grouped around a common vernacular theme, such as colors, poles, houses, pennants, or words.

COMPTON GALLERY

The Margaret Hutchinson Compton Gallery, located in the center of the main building complex and next to the Alumni Association offices, continued a program of exhibitions and events highlighting Institute activities. The gallery serves as a vehicle for informing visitors as well as community members of the wide range of Institute concerns and of its history.

Overall responsibility for the gallery is shared by the Compton Gallery Committee composed of Jim Hester, Executive Vice President of the Alumni Association; Kathryn Lombardi, Manager of the Campus Information Services; Warren Seamans, Director of Historical Collections; and Kathy Halbreich, Director of Exhibitions for the Committee on the Visual Arts. Jay Lucker, Director of Libraries, joined the Committee in the spring. Virginia Gunter, as Director of the Compton Gallery, was a part-time staff member of the Committee on the Visual Arts.

In addition to overseeing the planning of the past year's exhibitions, the Committee undertook a rigorous evaluation of the program's organizational structure. After serious deliberations, the Committee decided the present organization and part-time staffing of the Gallery was not adequate to meet all the needs for the planning and implementation of a professional exhibition program. The Committee, therefore, decided to place the operation of the gallery under the aegis of the Historical Collections, anticipating that the Collection's staff resources and research materials will allow the program to prosper in the coming year. The Committee is grateful to Virginia Gunter, departing Director, for demonstrating the potential of the Gallery and guiding its development during its first years. The Committee also recommended the addition of faculty, student, and alumni members. These organizational changes do not represent a departure from the original goals and objectives developed when the gallery was first planned.

The Exhibition Program

During the past year, the Compton Gallery presented four exhibitions: "The Computer: From Counting to Cognition," "Gjon Mili: A Photographic Exhibition in Two Parts," "Generations: The Story of Building 20," and "The Presidential Portraits."

The summer-long computer exhibition documented the history of counting and calculating methods by including early tools such as an abacus, Napier's "bones," a spiral slide rule, and a "millionaire" from 1895. This exhibition also highlighted MIT's own contributions to the development of the computer, including the research of Dr. Vannevar Bush and Professor Jay W. Forrester. A section of the show of particular interest to the general public was a display of a computerized chess game which viewers were invited to challenge.

On September 4, the gallery presented the photographs of Gjon Mili, a 1927 graduate of MIT, whose interest in lighting systems led to a productive working relationship with Dr. Edgerton, the inventor of strobe lighting. Mili became the first photographer to apply the strobe to photo-journalism. Through his association with *LIFE* Magazine, Mili produced numerous photo essays on the arts, 40 of which were included in the "Realized Moments" section of the exhibit. In the late 1950s Mili returned to MIT to photograph the people and places of his formative years; these

photographs were titled "MIT Revisited" and were included in the exhibit. A four-page brochure accompanied the exhibition which closed on January 31.

The exhibition "Generations: The Story of Building 20" opened on February 20. The exhibition focused on the history of Building 20, where the Institute's commitment to interdisciplinary and interdepartmental research began. Built during World War II for the Radiation Laboratory, the building came to be an incubator for numerous experimental projects. The exhibition documented these projects, and illuminated the relationship of the physical environment to evolving educational practices and programs. An advisory board consisting of faculty and staff associated with Building 20 devised a questionnaire which was sent to all known "residents" of the building. In addition to this information and to pertinent artifacts, video interviews with Honorary Chairman of the Corporation James R. Killian, Jr., Consultant to the President and Chancellor Albert G. Hill, Provost Rosenblith, President Jerome B. Wiesner, Professor Rainer Weiss, and Institute Professor Emeritus Jerrold Zacharias were included in the exhibition.

The final exhibition of 15 portraits and eight busts of MIT presidents was organized by the Historical Collections and opened on June 25. The exhibition continues through September. Explanatory texts included in the exhibition offer summer visitors insight into MIT's history.

Audience and Hours

The gallery, now in its third year, links the interests of faculty, students, and alumni. As awareness of the gallery's program has grown, many special functions have been coordinated with gallery viewing. Events held in conjunction with Technology Day, the Alumni Officers Conference, and the McCormick Scholarship Students luncheon were held in Compton Gallery. The regular weekday gallery hours of nine am to five pm were expanded during the academic year to include weekend visits.

Special Projects

A special five-part IAP lecture series was organized in conjunction with the Gjon Mili exhibition. The program examined various aspects of creating the photographic image. Mili gave a gallery talk and an informal critique of student work; MIT Professor William F. Schreiber demonstrated a computer-controlled system for receiving, storing, editing, and transmitting news photographs; Stanley Forman, Pulitzer Prize winner and news photographer, discussed how the image is found and isolated; and William E. Parker, Professor of Art and History of Photography at the University of Connecticut, illustrated how the selection of a photograph indicates personal vision. Videotapes of each of the lectures were made.

In order to strengthen the gallery's links to the Alumni Association, the Historical Collections, with the support of the class of 1917, organized an exhibition documenting the Institute's history which was installed permanently in the corridor leading to the gallery. Further collaboration with individual alumni and classes is anticipated.

BORIS MAGASANIK
KATHY HALBREICH

Division for Study and Research in Education

During the 1979-80 academic year, the Division continued to be active in its program of graduate education, in its research program, and in developing activities through which members of the MIT faculty could participate in discussion and action projects about the nature of learning and teaching. These activities are conducted under several auspices which will be briefly described in this report. First, it bears note that two major supporters of the Division have continued, indeed expanded, their most generous support. The Ford Foundation, which had made two developmental grants to the Division over the period of February 1976 to February 1980, has extended its second grant through the end of the 1981 fiscal year in order to support the Division in the development of a doctoral program in education and technology. In addition, Cecil H. and Ida M. Green, who have been most generous in their support of the Division, have awarded to MIT for the Division two career development chairs in education. These chairs will become active over the next two or three years -- the first being used to support a young faculty member in the Division, the second to provide "release time" for a small number of MIT faculty members each year who would like to pursue an educational or curricular topic with the collegueship of members of the Division. Both functions for a career development chair are most appropriate to the Division's goals, and we continue to express our appreciation to Cecil and Ida Green for their most generous support of the Division. In addition to the career development chairs, Mr. and Mrs. Green have made possible the appointment of Professor William T. Martin as Special Green Lecturer in Education. This special lectureship provided a most suitable way for the Division to recognize the many contributions to education at MIT which have been made by Professor Martin.

The Division continues its collaboration with other academic departments, centers, and laboratories at the Institute. Professors Daniel N. Osherson and Susan Carey continue to be active members of the Center for Cognitive Science and they provide a lively interchange between that Center and the Division. Professor Barbara Scott Nelson continues as a member of the Center's Advisory Board. The work of Dr. Sylvia Weir on cerebral palsied children extends the work of the Division into the area of learning disabilities, and continues the collaboration between the Division and the Whitaker College of Health Sciences, Technology, and Management. The College has recently expressed renewed interest in Dr. Weir's work and we expect a broadening of this collaboration. The Laboratory for Computer Science has provided substantial support for the work of Professors Harold Abelson and Andrea diSessa in the form of grants to support the development of an integrated computer environment.

During the past year several members of the Division served in important advisory capacities on programs of national and international importance. Professor Benson R. Snyder was a member of the advisory panel to the National Institute of Education (NIE) in the planning of a new research program on organization and management of post-secondary education. Professor Nelson was appointed a member of the study group on the NIE's research program on post-secondary education. Professor Judah L. Schwartz spent six weeks in Paris serving as a consultant to the French government in the establishment of a new national science museum for France.

Five regular activities of the Division continued on a very strong basis this year:

- 1) The working paper series, started last year with support from the Ford Foundation grant, has proved a successful mode of communication about the Division's intellectual program to scholars elsewhere. Three papers were published last year and three more are currently in varying stages of production. One of the former, Professor Jeanne Bamberger's paper entitled "Music and Cognitive Research: Where do our questions come from; where do our answers go?" has been in substantial national demand by members of the Cognitive Science and Music Education professions.
- 2) The Division continued its collaboration with the Program in Science, Technology, and Society and the Mathematics Department in support of the Norbert Wiener Study Group. Professor W.T. Martin and Visiting Professor Howard Gruber have played a major role in the establishment of this

study group. The group met three times during the academic year and heard the following papers: Steven Heims, a former Brandeis University physics professor, on "Wiener's Style of Innovation: Some Persistent Metaphors in His Thought"; and Professor Martin, Cecil and Ida Green Special Lecturer and Professor Emeritus, Education Division and Mathematics Department, "Norbert Wiener's Work on Brownian Motion and Some of Its Impact" (two sessions).

3) The Case Study Group, chaired by Professor Snyder and Visiting Professor Gruber, met regularly during the year to continue its inquiry into case studies as a method for gaining insight into the unfolding of individual lives and the understanding of unique institutional or societal events. The group was regularly attended by: Ms. Bamberger, Associate Professor of Education and Music, DSRE, MIT; Dr. Carey, Associate Professor of Psychology and Education; MIT; Dr. diSessa, Assistant Professor of Education, DSRE, MIT; Eleanor Duckworth, Research Associate, DSRE, MIT; Lynn Goldsmith, postdoctoral fellow, DSRE, MIT; Dr. Gruber, Professor of Psychology and Director, Institute for Cognitive Studies, Rutgers University; Inge Hoffman, Psychologist, Harvard University and Cambridge City Hospital; Thomas Kuhn, Professor of Linguistics and Philosophy, MIT; Kenneth Manning, Assistant Professor, Program in Science, Technology, and Society, School of Humanities and Social Science, MIT; Dr. Nelson, Assistant Professor of Education, Associate Director of DSRE, MIT; Dr. Snyder, M.D., Professor of Psychiatry, Director, DSRE, MIT; Vicky Steinitz, Lecturer on Education, Harvard University Graduate School of Education, Harvard University; Silvia Sutton, free-lance writer/editor, writer/editor of DSRE history 1978-79, MIT.

Major presentations were made by Professor Snyder on his study of MIT graduates, Professor Gruber on Darwin and Piaget, Professor Nelson on problem-setting in schools, and Professor diSessa on physics-learning by MIT undergraduates. Each of these projects is discussed in detail later in this report.

4) Professor Schwartz chaired a regular weekly meeting of the "Thursday Informal Group Interested in Mathematical Problem Solving." This group was composed of people interested in mathematical problem solving; and topics discussed ranged from pre-schooler's conceptions of number and elementary school mathematics curriculum development, to the use of microcomputers in education, and the teaching of mathematics at university level to students who are uncomfortable with the subject.

5) Finally, the Division's weekly luncheon seminar series provided the opportunity for 27 scholars to address the Division and the general MIT community on a variety of subjects related to cognition, psychological development, educational innovation, and reform. About one-half of the speakers were members of the MIT community, including: Dr. Snyder, Professor of Psychiatry, Director, DSRE; Dr. diSessa, Assistant Professor of Education, DSRE; Edwin Taylor, Director, MIT Educational Video Resources; Malcolm Parlett, Visiting Lecturer, DSRE, Director, Higher Education Study Group, Education Development Center; Michael Garet, Research Associate, DSRE; Dr. Richards, Visiting Assistant Professor, DSRE; John Terry, Lecturer, DSRE, Director Project STILE; Patrick Winston, Associate Professor, Department of Electrical Engineering and Computer Science and Director, Artificial Intelligence Laboratory; Wayne O'Neil, Professor of Linguistics and Humanities, MIT; Robert Lawler, Postdoctoral Fellow, MIT; Professor Samuel J. Keyser, Head, Department of Linguistics and Philosophy, Director, Center for Cognitive Science; Ray Pariser, Associate Director, MIT Sea Grant Program and Senior Research Scientist, Department of Nutrition and Food Science; and Evelyn Fox Keller, Visiting Fellow, MIT, Program in Science, Technology, and Society.

Distinguished guests provided the other half of the luncheon seminars. These included: Richard G. King, Director, Program Division, Museum of Science and Hayden Planetarium, Boston; Martin Trow, Professor of Sociology, Graduate School of Public Policy, Director, Center for Studies in Higher Education, University of California at Berkeley; Joseph B. Wheelright, M.D., Clinical Professor of Psychiatry, Emeritus, University of California at Berkeley and former President of the International Association of Analytical Psychology; Frederick Reif, Professor of Physics, Director of SESAME, Group in Science and Mathematics Education; Jacques Mehler, Editor, *Cognition*; Roslyn Linheim, Architect, American Institute of Architects (AIA), Professor of Architecture, University of California at Berkeley, Visiting Professor, DSRE; Robert I. Sperber, Superintendent of Brookline Public Schools; Ingrid Sommerkorn, Professor, Interdisciplinary Center for Higher Education, University of Hamburg; Lawrence Stenhouse, Professor of Education, Director, Center for Applied Research in Education, University of East Anglia, Norwich, England;

John Clement, Director of Research, Cognitive Development Project, University of Massachusetts at Amherst; Dr. Osherson, Clinical Psychologist, Massachusetts Mental Health Center; and Edwina Rissland, Assistant Professor, Computer and Information Science, University of Massachusetts at Amherst. (Full titles for the set of luncheon seminars are included in the archival version of this report.)

This year the Provost appointed an advisory council for the Education Division. The primary responsibility of this council is to keep itself informed of the Division's programs and activities-- its intellectual focus, its research and education programs, and its links with other MIT activities and concerns. Members include Professor Lotte Bailyn, chairperson, Professor of Organizational Psychology and Management, Sloan School of Management; Professor Margaret MacVicar, Professor of Physics; Professor Richard Held, Professor of Psychology and Department Head; Professor Daniel Kleitman, Professor of Mathematics and Department Head; Professor Keyser, Professor of Linguistics and Philosophy, Department Head, and Director of the Center for Cognitive Science; Professor Kent Hansen, Associate Dean, School of Engineering; Professor Wilbur Davenport, Professor of Electrical Engineering and Computer Science; and Professor Julian Beinart, Professor of Architecture. The advisory council met twice during the 1979-80 academic year.

ACADEMIC PROGRAM

The Division's academic offerings consisted of 21 graduate and undergraduate subjects of which five were joint with other academic departments, and one with the Program in Science, Technology, and Society. This number included three new subjects: 1) Theories and Methods of Qualitative Program Evaluation (Dr. Parlett); 2) The Developmental Psychology of Scientific Thought (Dr. Duckworth); and 3) Higher Education in American Society (Dr. Carl Kaysen, David W. Skinner Professor of Political Economy, Program in Science, Technology, and Society).

Seventy-six students enrolled in subjects offered by the Division this year, an increase of 13 over the previous year. In addition to offering subjects of instruction, the Division's faculty is supervising 12 doctoral students in joint programs with a number of MIT departments -- four with the Department of Urban Studies and Planning, three with the Department of Electrical Engineering and Computer Science, two with the Department of Psychology, and one each with the Departments of Mathematics, Mechanical Engineering, and the Sloan School of Management.

Two students were awarded the Ph.D.: Herbert Lin, jointly with the Physics Department, whose thesis was "Problem Solving in Introductory Physics: Demons and Difficulties," and William Ronco, jointly with the Department of Urban Studies and Planning, whose thesis was entitled "Participatory Work Organization."

During the past year the Division's faculty continued its work on the development of a Ph.D. program in education and technology. A draft document describing that program has been prepared and approved by the Division's faculty. We expect to begin discussions with the appropriate MIT faculty committees during the 1980-81 academic year, with a view of seeking formal approval for this program.

RESEARCH PROGRAM

The Division's budget has grown from less than \$300,000 in fiscal year 1974, to more than \$1 million in fiscal year 1980 -- over half of which is research sponsored by government agencies. Project support currently comes from the Bureau of Education for the Handicapped, US Office of Education; the National Institute of Education; and the National Science Foundation. In addition, several projects are supported by grants from the Ford Foundation, Texas Instruments, Inc., the Mattel Foundation, and several other private donors.

Professor Schwartz's study of "The Social Purposes and Intellectual Foundations of Educational Assessment" made good progress with support first from the Ford Foundation and then from the National Institute of Education. Since the beginning of the grant Professor Schwartz and Dr. Gareth

have developed a typology of assessment purposes organized by the kinds of judgments or decisions assessment is supposed to support, and have used the typology to organize the work of two study panels, one on assessment and instruction, the other on accountability. The panel of assessment and instruction, which had initially met during the winter of 1978-79, had a second meeting in February 1980. A set of papers culminating in a second volume, both to be published by the MIT Press, is expected next year.

Professor Bamberger's research into the process by which an individual restructures or takes a new view of a problem, situation, or idea has focused for the past two years on an experiment in teacher development funded by the National Institute of Education. Currently finishing its second year, this project has provided an extraordinarily rich source of data on how teachers think about their own learning and about the learning of children. This data will be analyzed in the coming year and we expect significant new findings about adult conceptual change to be forthcoming. It seems clear from inspection of the initial data that this seminar has been a major source of change for five of seven teachers in the group. Their sense of their roles as teachers, adults, and as learners has changed in very particular ways that still need to be made more explicit. In addition the teachers' sense of "schooling," what it is for, what it could be for, and what it has been for each of them, has changed in substantial ways.

In addition to her work on the thought of teachers, Professor Bamberger has been very active in developing theory of music education and has established a group called "The Group for Experimental Studies in Music and Cognition" (GESMAC). GESMAC is a consortium of performers, composers, and cognitive psychologists from various academic institutions in the Boston area. GESMAC grew out of their shared interests in the interactions among psychology, music, and education. The activities of the group include review of the current literature in psychology of music, music theory, epistemology and philosophy of science, as well as the design and implementation of experiments in the fields of music and cognition. The questions guiding the research developed from their mutual recognition of the discontinuities that arise between reflections on their own musical intuitions and their observations of the teaching-learning processes in the classroom. Thus, their studies explore the understandings of people with widely varying degrees of musical experience. In addition to Professor Bamberger, the group consists of Martin Brody, Wellesley College, Department of Music; Dr. Duckworth, MIT, DSRE; Lyle Davidson, New England Conservatory of Music, composer and theorist; Melissa Howe, MIT Music Section; Jessica Krash, Harvard University, Class of 1981-82; Susan Petrick, MIT, graduate student in Psychology; and Joyce Mekeel, Boston University, Department of Music, composer.

Professors Abelson and diSessa have continued work on their project to develop computer-based modules for MIT freshman subjects in mathematics and physics. They received a grant from the MIT IBM Fund to support the current year's work. In addition, together with Professors Martin and David Vogan of the Mathematics Department they conducted a weekly seminar, which several graduate students attended. The seminar discussions were on computer-oriented conceptual developments of, and computational environments for, elementary mechanics; fields -- electricity and magnetism; geometric optics; vector algebra; and statistical mechanics. The goal of the project is to develop a program in freshman mathematics and physics which has as its core the notion that many students can best learn technical concepts by formulating, testing, and refining their own intuitive models. Professors Abelson and diSessa want students to learn how to look at an unanalyzed phenomenon, recognize elements within it which are understandable in already known terms, recognize elements which are not understandable in such terms, and to formulate and carry out investigations which can lead to a testable explanation. This is a process in which students can learn the true nature of technical knowledge, both its function and limits, yet at the same time become more aware of the personal aspects of intellectually mastering a new problem area. The use of the LOGO computer environment may facilitate this process. The project will also serve as a clinical setting for investigating two central issues: how does the claim that knowledge develops through participation in active but not heavily structured environments relate to the acquisition of complex scientific knowledge, and to what extent is the notion of general intellectual development viable at the college level? Their research is, thus, closely linked to the "cognitive process instruction" movement, although most previous studies have tended to concentrate on problem solving while Professors Abelson and diSessa concentrate on the longer-term intellectual growth associated with the ability to formulate solvable scientific problems while at the same time learning to solve given problems.

Professor Roy Kaplow, under a grant from the Fund for the Improvement of Post-secondary Education, continued his work to design and implement a computer-based public facility with direct user-accessibility for the purpose of providing services in response to user-initiated requests, such as a referral service and an information bank. The project involves the Cambridge Public Library and the Cambridge Office for Community Development.

Professor Seymour Papert has continued his direction of a collaborative project with the Lamplighter School of Dallas, Texas, and Texas Instruments, Inc. to build personal microcomputers capable of running the LOGO computer language for children and to integrate them into the elementary school program of the Lamplighter School. The program builds on established links between MIT, Austin College of Sherman, Texas, and Texas Instruments, Inc. Ten microcomputers have been developed, and teachers from Lamplighter School have been trained to program the computers in LOGO and to guide young students in their explorations of the computer.

Under a grant from the HEW Bureau of Education of the Handicapped, Professor Papert and Dr. Weir have been investigating the use of the LOGO computer environment to study the learning of spatial and linguistic concepts in severely handicapped children. Research findings to date are most encouraging. Adolescent cerebral palsy students adapt readily to working in the computer environment as long as appropriate interfacing peripherals have been developed. Improvements have included specific gains in spatial and mathematic reasoning, as well as general gains in self-image and confidence.

Dr. Snyder has continued his interviews of members of the MIT Class of 1965 in order to examine in detail the long-term consequences of their adaptation to their passage through MIT on what they do now, who they are, and what they think and feel. This continuation of the Student Adaptation Study explores the interplay of psychological and social forces over an extended period of time in the development of professionals in science and engineering. The study also deals with a number of issues that go beyond particular concerns at MIT. The difficulty which engineers and scientists have in communicating across their disciplinary boundaries has often been observed. In many respects each discipline with its shared metaphors and modes of problem solving constitutes a subculture. A more refined understanding of the processes by which scientists and engineers become educated into and invested in maintaining their very specialized worlds is critical, and bears directly on our society's ability to sustain meaningful discourse among its members about the short- and long-term consequences of communication between the scientific establishment and the larger, "humanistic" culture.

Professor Nelson has begun a comparative study of the ways in which adults in public schools identify problematic situations, interactive processes by which such problems are identified as collective, and members' explanations for why the situations appear problematic. The study has both theoretical and practical significance. Problem setting is the result of a process in which some things have been selected for attention and others ignored according to a view, often tacitly held, of the nature of social reality. The identification of problems can thus serve as an indicator of that view of social reality, in particular of the assumptions about the nature of teaching, learning, and school as an organization held by various members of the school community. Practically, it is clear that schools and school systems are currently under considerable stress and will continue to be so for a number of years to come. The declining school-age population, combined with the constraints imposed by a sagging economy, are leading to the closing of school buildings, the reduction of the teaching force, cutbacks in ancillary school services, and so on. What school people perceive as problematic in such stressful situations and what they perceive to be solutions within their control to implement will be increasingly important issues.

Professor Donald A. Schon has been preparing a book entitled "The Reflective Practitioner," which explores the "unstable state" of the profession, arguing that all professions today, to one degree or another, in their practice contexts, their value frameworks, and their reservoirs of knowledge, have the characteristics of instability, variance, and uncertainty. Schon's book is devoted to the search for an epistemology of professional practice -- a view of the nature and grounds of practical knowledge which underlies our ideas about practical competence and its acquisition.

He also has been working with the Department of Urban Studies and Planning to develop a proposal for a five-year inquiry to be conducted jointly by the Department and the Education Division aimed at increasing our understanding of planning practice and improving our capacity to teach it. This

activity would consist of two studies: one, a study of the practice of professional planning, the other, a study of the teaching of practice. The project intends to bring these two studies together in a continuing seminar on planning practice and education for it. The seminar would include faculty affiliated with the Master in City Planning program and a small number of students together with some faculty and doctoral students from the Division.

RELATED PROJECTS

The WITS program (Work in Technology and Science) directed by Edith Ruina, Research Associate in DSRE, this year conducted a major program on technology-related careers for the Boston Public School System. Called "Technology and Science Careers for Minorities," the program provided workshops, site visits, career material, and classroom programs for educators from 16 Boston schools in an attempt to expand the awareness of educators about career opportunities and prerequisites in the technical sector, and to encourage them to make such opportunities known to their minority students.

The STEP program (Secondary Technical Education Project), through which MIT has aided the Boston Public Schools in their desegregation effort, faces a change in direction due to the resignation of its director, Dr. Stanley Russell. Having piloted the Umana Harbor School through its creation and early years, Dr. Russell has accepted the position of Superintendent of Schools in Shelton, Connecticut. The Umana School, which offers a scientific and technical education to students, grades 7-12, from all neighborhoods in Boston, has quickly become one of the most popular schools in the city.

PERSONNEL

Jeanne Bamberger, Associate Professor, was awarded tenure at MIT this year. The Division was pleased to have a number of long-term visitors in attendance this year. The following people were academic year visitors: Jerome Bruner held the appointment of Visiting Professor of Psychology and Education; he was previously and most recently Watts Professor of Psychology at Oxford University; Shlomo Libeskind, Associate Professor, Mathematics Department, University of Montana was a Visiting Associate Professor in DSRE; Pearla Neshier, Senior Lecturer (Associate Professor), The Hebrew University and Head, Mathematical Education Division, Haifa University was a Visiting Associate Professor in DSRE; Malcolm Parlett, Director, Higher Education Study Group, Educational Development Center, Newton, was a Visiting Lecturer in DSRE; and John Richards, Assistant Professor, Department of Philosophy, University of Georgia was a Visiting Assistant Professor in DSRE.

Shorter-term appointments to the Division included: Mimi Sinclair de Zwart, Professor of Psycholinguistics, University of Geneva, was a Visiting Professor in DSRE; Professor Roslyn Lindheim, Professor of Architecture, University of California at Berkeley, was a Visiting Professor in DSRE; Edwina Rissland, Assistant Professor, Computer and Information Science, University of Massachusetts at Amherst, was a Visiting Assistant Professor in DSRE; and Ingrid Sommerkorn, Professor, Interdisciplinary Center for Higher Education, University of Hamburg, was a Visiting Lecturer in DSRE.

Professor Papert, a member of the Division's faculty, was named the John Simon Guggenheim Fellow for 1980-81.

BENSON R. SNYDER
BARBARA SCOTT NELSON

Educational Video Resources

This report begins with examples of the wide variety of people in the MIT community who make use of Educational Video Resources (EVR), together with some numerical measures of these uses. We next outline the organization and policies designed to encourage such uses. The final sections describe some frustrations and some promising developments at the end of our first full year of operation.

The Variety of Users

A striking characteristic of video at MIT is the immense variety of people who make use of Educational Video Resources. Here are illustrative examples of this variety that include, in some cases, approximate numerical measures of use:

Video use in regular classes - The Physics lectures for 8.01 and 8.02 were taped and broadcast on the cable system the night before the next lecture, for review and make up. A total of approximately 70 lectures was recorded and broadcast for this class. In Mathematics 18.03 and Physics 8.01 and 8.02, a tutor answered questions on the weekly problem set for cable viewers, who could call in questions live from remote locations. Approximately 25 evening sessions of live help were held for these classes. Problem solution tapes in Electrical Engineering, prepared by Professor Alvin Drake, were broadcast on the cable for students in his class. Classic films were broadcast on the cable for film classes. Twenty different classic films were broadcast, and the number of films times repetition equals approximately 140. Two of the color portable video units in the EVR Equipment Library were reserved during the term for the exclusive use of a class at the Film/Video Section. Use of this equipment was heavy: in November 1979, for example, students in this class checked out the two reserve decks 23 times for a 54-day use out of a possible 60 days total for the two decks. Edwin Diamond's class in Rhetoric and Journalism met in an EVR studio, viewed clips of political TV ads, and discussed them with outside visitors. All of the sessions were videotaped and later broadcast on the cable system.

Video as class projects - A group of MIT and Wellesley students in Mr. Diamond's class recorded political news items off the air, edited them with commentary, and presented them to the class as well as over the cable system. A graduate student in the Science Communication Program taped an experiment on the causes of motion sickness at the Man/Vehicle Laboratory in the Center for Space Research, and edited it for a class project. The student Video Club wrote and produced the popular humorous quiz program "MIT 5.0." Some of the students received credit from the Film/Video Section for this task provided that they carried out an additional individual video project.

Use by artists and exhibitions - Antonio Muntadas of the Center for Advanced Visual Studies (CAVS) used EVR facilities to complete production of a pair of tapes that compared commercialized bull fighting in the town of Pamplona, Spain, with the more traditional celebration in rural Grazañalema. The display was produced for an April showing at the Guggenheim Museum in New York. Aldo Tambellini of CAVS used the cable system for interactive events within MIT and video slow-scan devices to link the following remote points by telephone line simultaneously: New York City, San Francisco, Austria, Japan, and Vancouver, Canada. Altogether, EVR worked with 11 fellows at CAVS who collectively carried out approximately 20 projects. As part of the Compton Gallery exhibit "Generations," which presented the history of Building 20, a series of MIT administrators and professors were interviewed on videotape about their experiences in that building during World War II and later.

Documenting Laboratory experiments - The Sea Grant Program commissioned EVR to produce a tape on their prototype dogfish skinning machine, which they used in encouraging equipment manufacturers to develop a commercial version. In cooperation with the Industrial Liaison Program, EVR began a project to tape some professors on a tour of their laboratories. This will show the equipment when it is working, and help to reduce the distraction some professors feel when many visitors come to tour the labs.

Community issues - Dr. John Kemeny reported on his experience as chairman of the Commission on the Accident at Three Mile Island. His speech was played live on the cable system, taped, rebroadcast, transcribed, and published in *Technology Review*. The Cambridge City Council met in November to discuss the disposal of radioactive waste from research facilities. EVR staff videotaped the proceedings for the Oral History Program for use in class, research in science and public policy, and for the Archives.

Special courses - The Center for Advanced Engineering Studies (CAES) produced approximately 45 hours of completed lectures this year for rental and sale to companies that wish to bring their engineers up-to-date on advanced topics. Approximately 80 hours are planned for the coming year.

The overall level of use of our facility has increased steadily. Some areas now operate around the clock. For example, during April 1980, as the term drew to a close, our 3/4" tape editing facility was used for 509 hours, which is 71 percent of the total number of hours in the month based on a 24-hour day and a 7-day week. During the year, the professional facility, which offers broadcast quality equipment, was used for approximately 1,300 hours of production, 2,700 hours of editing, and 700 hours for classwork by students in Film/Video Section.

Increased use means increased maintenance. During the year our one-person maintenance staff was increased to two. This staff repaired equipment not only for EVR but also for three academic departments, CAES, two libraries, and the Office of the President and Chancellor.

ORGANIZATION, POLICIES AND THEIR CONSEQUENCES

EVR has been in existence for about a year. It was reorganized under the Provost's Office in April 1979 from an operation formerly supervised by CAES. The first year has been concerned largely with locating and breaking in a new staff (including the Director) and cooperatively developing ways to encourage uses of video at MIT that may be generally termed "educational." Since April 1979 four staff members have left and seven (again including the Director) have been added. The total staff is now 10.

We have adopted a simple policy in order to encourage educational use of video: for such use we do not charge for equipment, facilities, or staff working during regular hours. Ordinarily we ask that the user provide for the cost of tape, for any students that must be specially employed to carry out the project, and, where funding is available, for staff time after hours. Tape is provided free of charge to the student Video Club, to our interns, and to some projects without funding. By and large, this policy has worked well, to the point that some of our facilities are overloaded for some months of the year.

For the upcoming year we intend to continue encouraging use while beginning to exercise priorities in light of what people find attractive and most useful. In applying these priorities, we will increasingly become actors and initiators, as well as providers of services to those who come to us.

Some Frustrations

The MIT Cable System is underutilized, even though it provides a natural outlet for all of the creative and educational programming that originates at the Institute as well as for material from outside sources.

There are about 1,000 cable outlets scattered all over the campus. To these outlets are attached approximately 25 public and semi-public monitors and roughly 150 private sets. Many dormitories have public monitors in their lounges, but most student dormitory rooms are not attached to the cable. The cable has a capacity of 18 channels simultaneously in each direction. At present we have equipment for three downstream channels and mobile equipment for bringing a program upstream from any of the 1,000 or so cable drops on campus. Early in the year the cable schedule amounted to three or four hours per day.

We have studied the sociology and architecture of the public monitors. There are not enough of them, and many are not in the right places. We have instituted an announcement system "Today

at the Institute" which has gone largely unnoticed. We have tried without success to encourage students to take over the operation of the cable system as a volunteer project and run it 24 hours a day. We have hired a part-time employee, and have used interns to increase the programming available to seven or so hours a day during the term. We have ordered converters to put the commercial TV channels on the cable, so that anyone on the cable with a converter can obtain excellent reception.

In spite of these measures, both the programming and number of viewers grow slowly.

Our professional facility, which includes a large studio with four studio cameras, a master control room with two broadcast quality two-inch tape recorders, and other equipment, is now about 10 years old. This equipment is continually breaking down at crucial moments, dominating the time and attention of our maintenance staff and endangering many of our most widely used products, including those that bring in the greatest amount of our income.

Promising Developments

Almost every new technology begins by being used in ways appropriate to previous technologies. Only with time and experience does one come to see how the new technology provides new opportunities for tasks that are themselves transformed by its presence. Recording and rebroadcasting lectures, live help sessions on the cable, and rebroadcasting of classic films and other "canned" video materials are examples of "previous technology" uses of video. Some other ideas noted below provide untested or only partly tested possibilities.

Twice we went into a laboratory and used our portable video equipment to tape a research professor explaining the experiments he is carrying out. Spontaneity is greatest if the presentation is without rehearsal. The result is a half-hour tape with no editing except for titles and credits. The production is quick, taking only an hour of the faculty members' time and three or four hours of our time. Such a production opens the laboratory to a large variety of observers: students in classes, prospective graduate students and UROP students, colleagues at the Institute and elsewhere, and funding agencies. As mentioned above, we are collaborating with the Industrial Liaison Program to produce more of these tapes.

A City Manager's commission in Cambridge is examining the possibilities for a cable system in the city. Would a channel assigned to local institutions of higher education increase the common ground between us and other universities, improve our relations with the community, help us to reach members of the MIT community living nearby, and provide an audience large enough to motivate students to run our cable system?

"Synapse," a video facility connected with Syracuse University, provides low-cost services to selected independent video artists for post-production of their work. Synapse equipment is of professional quality but of more recent vintage than ours, including computer control. How would such a program influence the visual arts at MIT?

We have become an attractive location for interns from Massachusetts colleges and universities with educational programs in communications. Some graduates of these programs are also willing to volunteer their time to work with us while looking for regular employment. Both kinds of help augment our staff while providing training to those involved.

EDWIN F. TAYLOR

Facilities Use

The Office of the Provost continues to formulate and implement policy for the use of Institute facilities by recognized MIT groups, guests from off campus, and by non-MIT organizations sponsored by faculty and recognized MIT groups. The Special Assistant to the Provost, Louis Menand III, is aided in these efforts by a committee comprised of Robert J. Holden, Associate Dean

Facilities Use

for Student Affairs; Carmen Besterman, Special Assistant in the Office of Chairman of the Corporation; Mary Morrissey, Director of the Information Center; and Winston E. Flynn, Assistant Registrar. This committee meets weekly to review facilities use requests.

Although use of MIT facilities is in part governed by the Institute's tax-exempt status, basically facilities use should contribute to the enhancement of purposes for which the Institute has been chartered, with primary focus on its educational and research roles. MIT facilities may not be used directly to support candidates for public office or for lobbying for particular legislative issues, nor may the Institute's facilities be used to support profit-making organizations.

The domain over which this committee presides includes all of the academic space at the Institute, the Julius A. Stratton Student Center, departmental memorial rooms, and the like. Inevitably this office and the facilities committee are drawn into broader issues involving controversial and difficult potential uses of MIT facilities. As a consequence, the Office of the Provost is frequently consulted on a wide range of political, social, and even religious issues stemming from facilities use. For example, the appropriateness of activities suggested for IAP in January of each year is reviewed by the Special Assistant to the Provost who frequently consults the Committee as well as other appropriate offices within the Institute.

During 1979-80, the Institute was host to, among others, the Triennial Meeting of the World Council of Churches, the Acoustical Society of America, the Ninth Annual New England Bioengineering Conference, the Eighth International Conference on Magneto-hydrodynamic Electrical Power, and a conference on Technology Innovation and Industrial Development sponsored by the Center for Policy Alternatives.

The presentation by undergraduates of talks by candidates for public office is considered to be educational in nature, and therefore provision was made for the appearance of candidates for the office of President of the United States, including John Anderson, Harold Stassen, and Edmund G. Brown.

The scheduling of facilities was particularly complex during 1979-80 because Kresge Auditorium was closed in early September for emergency repairs to its roof. Kresge remained closed throughout the academic year. Provisions were made for drama presentations at the Loeb Drama Center (Harvard University) and the Hasty Pudding Club (Harvard University). Musical programs were rescheduled at Walker Memorial on campus and at Jordan Hall (New England Conservatory of Music). The Abramovitz Lecture, this year an opera by Professor John Harbison entitled "A Winter's Tale," was presented in John Hancock Hall. For the use of such resources, the Institute expresses its appreciation.

LOUIS MENAND III

Harvard-MIT Division of Health Sciences and Technology

In June 1980, the Harvard-MIT Division of Health Sciences and Technology submitted a report to the Governing Board for the period 1969-80, from the inception of the Harvard-MIT Program to the present. This annual report presents some of the highlights of the report to the Governing Board.

After two years of intensive study and exploration by faculty committees of Harvard University and MIT, a formal proposal was presented to the faculty of Medicine and the faculty of Public Health at Harvard and to MIT's faculty in 1970. This proposal was for the establishment of a joint Harvard-MIT institution in the health sciences and technology to foster the development of health-related programs of education, research, and service, provided that the necessary new resources could be obtained. After favorable votes by these faculties, the Corporation of MIT and the Corporation at Harvard endorsed the resolution in June 1970. The decision was made to proceed first with the creation of a joint Program, the development of appropriate curricula, the design of the organizational structure, and the acquisition of the necessary supporting funds. The initial goal for fund raising was set at \$10 million of endowment.

A curriculum in the biomedical sciences leading to the M.D. degree awarded by Harvard Medical School was inaugurated in 1971. This curriculum, jointly taught by faculty members of MIT and Harvard University, is oriented toward students with a strong background in quantitative science. Twenty-five students per year, about equally divided between the physical, chemical, engineering, and biological sciences, are admitted as candidates for the M.D. They are all expected to engage in independent scholarly work and are required to submit a thesis prior to graduation. Approximately 30 percent of the students work for a Ph.D., as well as the M.D., in various branches of the biological sciences, and in chemistry, physics, and engineering; some venture further afield to economics, anthropology, and history. Most of these students appear to be headed for careers in academic medicine to engage in research, teaching, and health care.

A second major educational program in Medical Engineering and Medical Physics was inaugurated in 1978 after two years of thorough planning by faculty members of the two universities. This program is directed by Professor Ernest G. Cravalho, Associate Director for Medical Engineering and Medical Physics (MEMP). It is designed to produce highly qualified engineers and physicists who are also knowledgeable in human biology and medicine. With such strong backgrounds in the physical sciences and engineering and in human biology and medicine, these students should be well-qualified to engage in clinical investigation on important medical problems. Ten students are admitted each year as candidates for a Ph.D. at MIT or at Harvard University and are simultaneously admitted as Master's degree candidates in physics or in a department of engineering. Although the experience with the program is quite limited, it appears to be attracting students of very high quality who are performing very well both in engineering and physics and in the courses in the medical sciences.

After seven years of experience with the educational and research activities of the Harvard-MIT Program, and after the raising of \$8.5 million of endowment, the Governing Boards of the two universities decided to proceed with the development of a stable institutional structure which would: 1) be an integral part of the two universities, 2) provide a framework for interdisciplinary educational 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 and thus enhance the chances of obtaining the requisite financial support.

The term Division was chosen as the name for this administrative and academic structure rather than the original term, School, which had been proposed in 1970, since School has different meanings at Harvard and at MIT. Accordingly, in 1977, the Harvard-MIT Division of Health Sciences and Technology was established by vote of the Corporations of MIT and Harvard University.

In joining the two universities in common educational and research programs, the Harvard-MIT Division has been anchored at Harvard in a well-organized faculty of Medicine. At MIT, however, despite very extensive educational and research activities related to health and medicine, no similar administrative and academic focus existed. There was a clear need for an appropriate administrative structure within MIT which would provide a home for the MIT components of the Harvard-MIT Division. These programs included the Biomedical Sciences curriculum, the Medical Engineering and Medical Physics Program, and interuniversity research activities. In addition, there was the need for an academic structure to develop the full range of educational, research, and service programs envisaged in the proposal approved by the MIT faculty and Corporation in the spring of 1970. To help meet these needs, the Whitaker College of Health Sciences, Technology, and Management was established at MIT in 1978. The MIT components of the Harvard-MIT Division are an integral part of Whitaker College; the Harvard components of this Division are principally within the Harvard Faculty of Medicine.

The recruitment of faculty members for participation in the educational activities of the Health Sciences and Technology (HST) Division is carried out by the director and associate director with the help and advice of department chairmen, and with suggestions by other HST faculty members. Frequently, faculty members in the two universities volunteer to participate in HST courses. Until the present time, recruitment of new faculty members who are not members of the faculties of either university has been very seriously restricted because of the unavailability of research space for such new appointees. Indeed, the physical facilities available to the Division

consist only of teaching laboratories and classrooms that have been renovated in Building 4 of MIT, with headquarters in Building 16 of MIT and in Building E of Harvard Medical School, and offices and laboratories of the Biomedical Engineering Center for Clinical Instrumentation in Building 20 at MIT. It is only with the completion of the Whitaker College building at MIT in 1981 that new research space to house faculty members of the HST Division will be available.

One of the objectives in the establishment of the HST Division was the provision of career paths for faculty members, especially those working at the interfaces of human biology and medicine with the other sciences fundamental to biology and medicine. Teaching in a multidisciplinary, interfacial setting imposes an especially heavy responsibility and burden on the faculty member. What is more, it is significantly more hazardous for a junior faculty member to engage in such teaching and research because his or her discipline-oriented department may be much less appreciative of the productivity of the work, in part because it is not in line with classical fields. It is not surprising, therefore, that recruitment of faculty members for teaching in the HST Division, especially when it involves learning a great deal about another field, has been conducted principally among tenured faculty members. Junior faculty members are understandably anxious about the hazards of engaging in such teaching, especially when the rewards are by no means assured. The record on achievement of tenure or promotion to a professorship without limit of time is too meager to permit generalization. The system will not be adequately tested until such time as new primary appointments at non-tenure level are made in the HST Division and the results of those tenure decisions will be known.

EDUCATIONAL PROGRAMS

The Biomedical Sciences Curriculum

The curriculum is oriented towards students with strong backgrounds in quantitative science. In practice we have found that approximately one-half of the students who are successful applicants have concentrated principally in the physical sciences, i.e., mathematics, physics, engineering, or chemistry or in the biological sciences, especially molecular and cellular biology. An occasional student in the social sciences or in the history of science is admitted. Approximately half of the students admitted come from Harvard College and MIT, and the rest derive from major universities in this country.

The HST Admissions Committee for the biomedical sciences curriculum serves as a subcommittee of the Admissions Committee of Harvard Medical School. In general, the recommendations are accepted with rare exceptions by the Admissions Committee of the Medical School. When students are accepted for the regular curriculum of Harvard Medical School as well as the HST curriculum, they may choose either program.

The special features of the HST curriculum in the biomedical sciences derive from several basic principles. This curriculum seeks to bring to bear on the education of physicians the full range of sciences basic to human biology and medicine. These sciences include molecular and cellular biology, genetics, immunology, the chemical sciences, the physical sciences and engineering, and mathematics. In addition, as a major service in our society, health care engages the social sciences such as economics, sociology, political science, management, and public administration. Ethical issues are of major importance in the conduct of research and in health care. Fundamental to the understanding of human behavior, normal and abnormal, are the sciences of psychology and anthropology. In seeking to relate these sciences to the study of medicine, we have had to be selective because of the limited availability of faculty members and, more significantly, the pressures of time available for educational offerings that are appreciably different in content from those in a standard medical curriculum.

The evolution of the curriculum reflects the interplay of two principal attitudes. One attitude emphasizes the importance of experimental approaches aimed at introducing the full range of sciences basic to medicine. The other view stresses the essential professional education needed for individuals licensed to practice medicine. For some, the HST curriculum may not be sufficiently experimental or radical; for others, it may seem to be concerned with interesting but peripheral issues that distract students from the central core of medical studies.

Several efforts were undertaken in an attempt to help promote penetration of the physical sciences into human biology and pathophysiology. Physicists and engineers were invited and persuaded to participate actively in the teaching of various courses in the medical sciences. They had to expend a great deal of effort in seeking to understand the physical basis of biologic phenomena. In several courses this effort has proved to be very productive and valuable, e.g., in Cardiovascular, Respiratory, and Renal Pathophysiology and in the Functional Anatomy of Man. To prepare students for a physical science approach to Pathophysiology, a new course, Quantitative Topics in Physiology, was developed by Felix Villars, Professor of Physics at MIT, and his associates who are physicists and engineers. This course has become progressively more effective in preparation of the students for the approach described. In other courses, in which quantitation is more difficult because of the unavailability of the data required for such quantitation, a more qualitative approach emphasizing molecular and cellular biology and biochemistry was indicated. This approach has proved to be particularly valuable in such courses as Hematology and Gastroenterology.

To help broaden the perspectives of the students, courses were developed on the Economics of Health Care and on Ethics and Decision Making in Medicine. These courses have proved to be successful, but the problem of providing stable faculty for continued teaching of these courses remains.

The teaching of the sociology of medicine, the social determinants of health and illness, health policy, and the biological basis of human behavior are inadequately represented in the HST curriculum. These deficiencies will be considered in the future plans of the Division.

Concentration and Thesis

A feature of the HST curriculum from its inception has been the requirement that each student choose a field of concentration in which he or she spends several months of elective time. Faculty tutors provide guidance in the choice of subjects and in the pursuit of independent study. Beginning in 1974 with the entering Class of 1978, HST students have been expected to engage in independent study and to present evidence of scholarly work in the form of a thesis based on laboratory research, clinical investigation, critical analysis of a significant medical problem or other activities approved by the faculty tutors. In many instances, these theses have been submitted for honors in a special field at the time of graduation with the M.D.

M.D.-Ph.D. Program

Many HST students engage in a combined M.D.-Ph.D. program in preparation for careers in academic medicine. Graduate study for the Ph.D. may be pursued at Harvard Medical School in the Division of Medical Sciences, at Harvard University in the Graduate School of Arts and Sciences, or in the Graduate School of MIT. The Ph.D. may be earned not only in the biological and basic medical sciences but in a wide range of fields including mathematics, physics, various branches of engineering, chemistry, anthropology, the social sciences, and history.

Since the inception of HST, 16 students have received the Ph.D. or completed the requirements for it.

Of the 57 candidates at Harvard Medical School for the M.D. and Ph.D. degrees this year, 36 (63 percent) were HST students, 22 at Harvard University, 14 at MIT. At Harvard, the departments and programs represented are Biological Chemistry, Physiology, Cellular and Developmental Biology, Biophysics, Neurobiology, Anatomy, Pathology, Pharmacology, and Physics. At MIT they are Biology, Nutrition and Food Science, Psychology, Medical Engineering and Medical Physics, Electrical Engineering and Computer Science, Mechanical Engineering, and Chemical Engineering.

Performance Evaluations

Two forms of course reviews have been operative since the inception of HST: annual reviews by students in response to a questionnaire with a detailed critique of the structure, content, quality

of teaching, syllabus, and examinations at the end of each course; and formal reviews at intervals of two to three years of each HST course by the Curriculum Committee. Course reviews in which students and faculty participate actively have been a most important feature of the HST curriculum and have guided the evolution of HST course offerings.

On the whole the students have performed very well in both the preclinical sciences and in clinical medicine. They have been awarded excellent internships and residencies in outstanding university teaching hospitals.

Since HST courses are graded Pass/Fail, it may be difficult to evaluate the performance of HST students as judged by general honors at graduation or by election to Alpha Omega Alpha, the honor society. During the period under review general honors were not awarded at Harvard Medical School and election to Alpha Omega Alpha was discontinued after 1977. Honors in a special field were awarded throughout the period under review.

HST students constitute 15 percent of the Harvard Medical School student body. During the years 1975-80, 73 students graduated with honors in a special field; of these 26 were HST students. In 1980, 73 percent of the students graduating with special honors were HST students. Numerous prizes and awards for outstanding scholarship and/or research have been won by HST students on graduation from Harvard Medical School.

A survey of the graduates of the first four classes of the HST Biomedical Sciences curriculum was conducted by written questionnaire and by follow-up telephone calls. In the first graduating class of 20 students in 1975, four hold full-time faculty positions, three have part-time faculty positions while engaged in the practice of medicine, eight hold research fellowships, three are still in clinical training and two are engaged in private practice. A similar pattern obtains for the Class of 1976. In the subsequent classes most of the graduates are still in clinical training or in research fellowships.

Although the sample is still small and the results are quite limited, the trend indicates a strong predilection for careers in academic medicine, in which teaching, research, and patient care are combined. The distribution among the fields indicates a significant concentration in internal medicine, but with appreciable numbers entering surgery and pediatrics.

Responsibility for the development of this curriculum has resided with the Curriculum Committee composed of HST faculty members and students. The Curriculum Committee reports regularly to the Joint Faculty Committee, the senior policy-making group of the Harvard-MIT Division. It conducts periodic reviews of courses and considers the content and mode of presentation of new courses designed to meet perceived needs. This committee provides a valuable forum for productive and constructive interaction of faculty members and students in the evolution of the biomedical sciences curriculum.

Medical Engineering-Medical Physics

During the past year this program, under the supervision of Professor Ernest G. Cravalho, Associate Director for Medical Engineering and Medical Physics, has continued to evolve. The major developments in the curriculum have been focused in the clinical year. Three students participated in clinical rotations in medicine, surgery, and cardiology. Professors Roger Mark and Walter Abelmann with assistance from Dr. Charles Hatem and Professor Walter Olson organized and presented HST-201 Introduction to Clinical Medicine and Medical Engineering I, at the Beth Israel Hospital and the Mt. Auburn Hospital. This clinical experience focused on physical diagnosis and patient history-taking in a manner similar to HST-200 Physical Diagnosis and Introductory Clinical Experience, taken by the biomedical sciences students. However, HST-201 has been expanded to encompass instruction in the manner in which technology has penetrated medicine as well as its costs, limitations, and abuses. This clinical experience was followed by HST-202 Introduction to Clinical Medicine and Medical Engineering II, a rotation in medicine presented at the Beth Israel Hospital by Professors Mark and Abelmann. In the spring term students were engaged in HST-203 Clinical Experience in Medical Engineering, encompassing two separate clinical experiences: Surgery with Drs. Herbert Hechtman and James Weaver at the Peter Bent Brigham Hospital and Cardiology also at the Peter Bent Brigham under the supervision of Drs. Thomas Smith and John Rutherford and Professor Olson. In the latter two experiences, students were exposed to patient care and to research while pursuing further study in these clinical areas.

Other curriculum developments in the program include HST-582 Biomedical Signal Processing, presented by Professor Robert Kenyon, Assistant Professor of Aeronautics and Astronautics, and HST-544J Fields, Forces and Flows: Background in Physiology, a subject formerly offered only in the Department of Electrical Engineering and Computer Science by Professor Alan Grodzinsky. In response to a need expressed by the students in the program, a new subject HST-570 Introduction to Electronics, was developed by Drs. Stephen Burns and John Tole to provide an introduction to instrumentation for those students with a deficiency in this area.

Now that this program has completed its second full year of operation, the faculty have begun to reflect on its structure and flaws for further evolution. A major issue under discussion is the desirability of an option for the M.D. degree for MEMP students. On the one hand, it is believed that the M.D. is desirable, if not essential, for those individuals engaged in clinical investigation, while on the other hand it is believed that the availability of such a degree may sidetrack some students away from research and lead them into the practice of more traditional forms of medicine. To provide the greatest flexibility, a proposal is being developed to provide opportunities for pursuit of the M.D.

In an attempt to expand the program in the physics area, the existing Radiological Physics Program presently offered by the Harvard School of Public Health and the MIT Department of Nuclear Engineering is under review. This effort, under the leadership of Dr. Bengt Bjärngard, Joint Center for Radiation Therapy; Professor Gordon Brownell, Department of Nuclear Engineering, MIT; and Professor Cravalho, is attempting to broaden the scope of the program to include radiochemistry, radiobiology, and health physics in addition to the more traditional aspects of radiological physics. This group expects to have completed the reformulation of the program during the 1980-81 academic year.

In this effort, the Division is fortunate to share the services of Professor Alan Nelson who was appointed Assistant Professor of Nuclear Engineering and Health Sciences and Technology in July 1980. Professor Nelson, a biophysicist, will assume responsibility for subjects in the area of the interaction of radiation with biomaterials.

With the support of the Kieckhefer Foundation, the Division sponsored on April 13-16, 1980, a national symposium entitled "Critical Issues in Medical Technology-Innovation, Diffusion, Utilization, and Cost" chaired by Dr. Barbara McNeil, Associate Professor of Radiology, Harvard Medical School, and Professor Cravalho. This symposium was an attempt by the Division to address the broader dimensions of medical technology and to establish a research agenda in the field of technology assessment. Based on this conference, Drs. McNeil and Cravalho are editing a book to be published in early 1981 that attempts to cover the entire spectrum of economic, legal, social, and ethical issues of health care.

Courses and Faculty

The Division has provided a stimulus for the development of 72 new subjects. Of these, 53 are continuing and 19 have been phased out. The Division provided support for the initial development of 71 and support for the continued presentation of 53. Twenty-two of the courses are in the medical sciences, 18 in bioengineering, 10 in the social sciences, eight in medical engineering and medical physics, six in medical radiological physics, five in physics, two in human biology, and one in biophysical chemistry.

Educational programs under the auspices of the Division have engaged 307 faculty members with 119 currently serving as members of the HST teaching faculty. Of the 307 faculty members, 61 percent were from Harvard Medical School, 25 percent from MIT, 4 percent from other Harvard faculties, 4 percent from the staffs of Harvard-affiliated hospitals, and 6 percent from other institutions.

Enrollment in HST courses for the eight-year period of fiscal year 1972 to fiscal year 1979 totaled 4,118. Of this total enrollment, 71 percent were HST M.D. candidates, 14 percent non-HST MIT students, 8.7 percent HMS students, and 6.4 percent other Harvard students.

RESEARCH PROGRAMS

Programs under the aegis of the Division focus on major medical and health problems and span the range from fundamental research to applied research, development, and clinical testing. The Division seeks to bring together teams of physicians, engineers, and scientists from Harvard Medical School, its teaching hospitals, and MIT to work on a scale appropriate to the dimensions of the problems under study. Emphasis is placed on the development of major interdisciplinary programs with high potential for productive and valuable results. Since the first HST research program was funded in 1972, seven comprehensive research programs consisting of 97 interdisciplinary research projects have been launched. These programs have received \$21 million of research support over the last eight years, mostly from Federal agencies.

Three major centers have been established: the Biomedical Engineering Center for Medical Instrumentation, the Center for Health Effects of Fossil Fuels Utilization, and the Rehabilitation Engineering Center at the Children's Hospital Medical Center and MIT. Research funds have grown from \$987,000 in fiscal year 1973 to approximately \$4.8 million in fiscal year 1980. Dr. Irving Berstein is Assistant Director for Research Program Development.

STUDENT AID AND FINANCIAL RESOURCES

In 1980 scholarships made up 22 percent of the total financial aid to HST M.D. candidates with the balance provided by loans. The Ph.D. candidates in the Medical Engineering and Medical Physics Program have been fully supported by fellowships. The current HST endowment principal pledged for student aid is \$941,000. Approximately one-half of fiscal year 1980 expendable gifts was raised specifically for student aid. In its 10 years of operation, the Office of the Assistant Director for Resources, Dr. Walter L. Koltun, has raised approximately \$12.5 million, \$9 million for endowment, \$3 million for operations, and \$0.3 million for physical facilities.

IRVING M. LONDON

Whitaker College of Health Sciences, Technology, and Management

During the past year, the Whitaker College Faculty Advisory Council has been exploring programmatic directions in the three areas of health sciences, technology, and management. The committee (listed at the end of this report) was aided by several other faculty members in narrowing options and focusing on specific research and educational paths to be taken. Three foci have been identified: human biology and experimental medicine, biomedical engineering and biological physics, and health policy and management. In the area of human biology and experimental medicine, the following factors are being considered in the choice of new programs: 1) major causes of human disease; 2) programs that complement current efforts at MIT; and 3) areas in which MIT's human and physical resources provide exceptional opportunities for productive development. In this context, research and educational programs in human genetics, atherosclerosis, infectious diseases including parasitic infections, neurosciences, and toxicology and environmental biology have been identified as promising fields.

In biomedical engineering and biological physics similar considerations apply, but the major emphasis is on the extension of existing strengths beyond those presently available in physics or engineering, particularly in those areas for which extensive knowledge in the life sciences is important. For example, research and educational programs are being developed in quantitative physiology (sensory physiology and cardiac electrophysiology), communication sciences, and imaging systems. These areas connect one to another and interface with current departmental and interdepartmental efforts.

In health policy and management, new efforts will consolidate existing activities in health policy, management of health care systems, and economics of health care delivery and research. Joint doctoral programs between departments and Whitaker College are presently under development. These programs draw on a common academic core now being developed for this purpose.

Recruitment of qualified faculty in these various areas is beginning. In the atherogenesis/thrombosis area of human biology and experimental medicine, two faculty appointments are nearly complete. Faculty searches in the neurosciences, human genetics, sensory physiology, and infectious diseases are in their initial stages.

Professor Ernest G. Cravalho, Associate Director for Medical Engineering and Medical Physics, Harvard-MIT Division of Health Sciences and Technology and Matsushita Professor of Mechanical Engineering in Medicine at MIT, and Professor Christopher T. Walsh, Professor of Biology and Chemistry at MIT have been appointed Associate Directors of the College. Laura J. Shapiro has been appointed Assistant to the Director.

The Whitaker College building, the physical plant to house these faculty and their teaching and research activities, has been under construction since June of 1979 with completion scheduled for August of 1981. As of September 1980, the exterior shell has been completed with some interior spaces in advanced stages of construction.

WHITAKER COLLEGE

Faculty Advisory Council

David Baltimore, Ph.D.
American Cancer Society
Professor of Microbiology
Department of Biology

George B. Benedek, Ph.D.
Alfred H. Caspary
Professor of Physics
Department of Physics

Emilio Bizzi, M.D.
Eugene McDermott Professor in the
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Department of Mechanical Engineering
Associate Director, Whitaker College
Associate Director for Medical Engineering
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Division of Health Sciences and Technology

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Lester Wolfe Professor of Molecular Biology
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Richard M. Held, Ph.D.
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Boris Magasanik, Ph.D.
Jacques Monod Professor of Microbiology
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Department of Mechanical Engineering

Edward W. Merrill, Sc.D.
Carbon P. Dubbs Professor of Chemical Engineering
Department of Chemical Engineering

Walle J. Nauta, M.D., Ph.D.
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Professor of Neuroanatomy
Department of Psychology

Lisa R. Peattie, Ph.D.
Professor of Urban Anthropology
Department of Urban Studies and Planning

Alexander Rich, M.D.
Professor of Biophysics and
Sedgwick Professor of Biology
Department of Biology

Edward B. Roberts, Ph.D.
David Sarnoff Professor of Management
of Technology
Sloan School of Management

Melvin H. Rodman, M.D.
Professor of Medicine
Director, MIT Medical Department

Independent Activities Period

Harvey M. Sapolsky, Ph.D.
Professor of Public Policy and
Organization
Department of Political Science

Peter Temin, Ph.D.
Professor of Economics
Department of Economics

Felix M.H. Villars, D.Sc.
Professor of Physics
Department of Physics

Christopher T. Walsh, Ph.D.
Professor of Biology and Chemistry
Departments of Biology and Chemistry
Associate Director, Whitaker College

Thomas F. Weiss, Ph.D.
Professor of Electrical and Bioengineering
Department of Electrical Engineering and
Computer Science

Gerald N. Wogan, Ph.D.
Professor of Toxicology
Underwood-Prescott Professor of Nutrition
and Food Science
Head, Department of Nutrition and
Food Science

Richard J. Wurtman, M.D.
Professor of Neuroendocrine Regulation
Department of Nutrition and Food Science

Laurence R. Young, Sc.D.
Professor of Aeronautics and Astronautics
Department of Aeronautics and Astronautics

Members ex officio of the Faculty Advisory Council are Dr. Jerome B. Wiesner, President; Professor Walter A. Rosenblith, Provost; Professor Sheila E. Widnall, Chairman of the Faculty; and Dr. Irving M. London, Director of Whitaker College and Director of the Harvard-MIT Division of Health Sciences and Technology.

IRVING M. LONDON

Independent Activities Period

Independent Activities Period (IAP) marked the end of its first decade in January 1980 with a record 550 activities, organized by volunteers throughout the Institute.

In many of these activities, people turned their attention to the energy crisis, discussing the technological, political, and economic issues involved and seeking solutions to practical problems, such as the design of more efficient fireplaces.

Members of the MIT community used the occasion of IAP's 10th birthday to reminisce about the past and look toward the future at a festive party with balloons and cake, given by the Lobby 7 Committee.

Because this year's emphasis on energy was both predictable and appropriate, the IAP Policy and Administrative committees decided early in the summer to facilitate the scheduling and publicizing of such activities for IAP '80. One of the special features of IAP is that it provides people with an opportunity to confront current issues. Unlike subjects for the regular semesters which are scheduled a year in advance, IAP offerings are organized in October and November, only a few months ahead of their occurrence. Since the inception of IAP, members of the MIT community have used the three weeks to work on energy-related issues; in fact, in almost any year more activities have dealt with energy than any other topic. However, this year with everyone being personally affected by the energy crisis, members of the IAP Policy and Administrative committees could foresee that the number of energy activities would be greater than ever before. To accommodate this emphasis on energy, the committee members set up a special clearinghouse in the Schedules Office where organizers of energy-related activities could register their schedules to prevent conflicts. In addition, the committees decided that energy-related activities would be highlighted in the *IAP Guides* under a special energy logo.

Activity leaders designated 63 of the 550 Guide Listings as "energy-related." Under the title "Energy: What is the Problem?" Professors Arthur G. Hill, Rainer Weiss, David White, and

Provost

Jerrold R. Zacharias led two half-day seminars in which they tried to enumerate the issues and evaluate different energy sources. In another activity, Professor John N. Newman of the Ocean Engineering Department delivered two lectures on one alternative energy source, the conversion of ocean-wave power to a usable form, while in an alternative offering, Sallie Chisholm, an assistant professor of Civil Engineering, looked at such systems as the bioconversion of wastes, that would make rural areas of developing countries self-reliant for energy and food. Also in Civil Engineering, Assistant Professor Harry Hemond explained why in New England there is a revival of interest in small-scale hydroelectric technology. Other activities dealt with electric power systems, solar energy, nuclear energy systems, fusion research, oil from shale, and synthetic fuels.

People also looked at all levels of energy economics, including the impact of higher prices on the poor, the causes of gas lines, the effects of an energy tax, the economics of alternative energy sources, and financial aspects of international oil markets. Faculty members in Mechanical Engineering led groups in discussing the design of automobile engines, synthetic fuels, fireplaces, and underground houses. Outing club members sought help in designing energy sources for a mountain cabin, while a member of the Libraries staff gave advice on keeping warm with quilts and puffs.

The always exciting spectrum of events that has characterized IAP for 10 years continued in 1980. One of the most unusual approaches to an academic subject was presented by Edward Merrill, Carbon P. Dubbs Professor of Chemical Engineering, who combined a French cooking class with a lecture in chemistry. Not only did he offer recipes and demonstrations for making mayonnaise, meringues, crepes, and other delicacies, but he also explained the chemical principles involved. In another offering mixing the academic with the practical, four mathematicians answered the question "What is Statistics?" by offering a series of lectures explaining insurance rates, batting averages, record-breaking years, and the Massachusetts Numbers Game.

The series on statistics was one of many put together by departments and laboratories to introduce students to their disciplines. In the Literature Section of the Humanities Department, faculty members designed a combination film-lecture series, "Books and Movies," in which participants viewed seven different films that are based on literary works, from *Frankenstein* to *The Blue Angel*. After each film a team of faculty members discussed the film and its relation to the original text. Other lecture series focused on biology, cancer research, operations research, the nature of intelligence, logic, aeronautics and astronautics, sea-level changes, and physics.

Among the hands-on activities were courses in bookbinding, glassblowing, welding, measuring thicknesses of materials, photography, holography, and building aluminum bicycle frames. The School of Engineering and the Information Processing Services (IPS) jointly sponsored an intensive introductory course in Fortran for 150 students. This was the first such collaboration between academic departments and IPS, and the first course IPS has designed primarily for students.

IAP policy is supervised by a faculty-student committee appointed by the President. Members of the IAP Policy Committee this year were: Professors Woodie C. Flowers (chairman), Catherine V. Chvany, Ernest Cravalho, Kenneth Hale, Robert O. Ritchie, Robert M. Rose, Robert J. Silbey, J. Edward Vivian, and Eric A. von Hippel; Joel Orlen, and Elizabeth A. Peralta.

Administration of IAP is accomplished in large part through the rotation of staff volunteers from departments and other offices of the Institute. This year the IAP Administrative Committee included: Margaret S. Richardson (chairman), Barbara J. Adams, Martha Bertrand, Philippa Bovet, Elizabeth C. Bradley, Mary Z. Enterline, Edward Gaudiano, Stanley G. Hudson, Daryl Hymoff, Patricia Joffee, Deborah Lanney, Charles Markham, Barbara McCarthy, Louis Menand III, Susan Morris, Mr. Orlen, and Jane Sauer.

Responsibility for overseeing IAP rests with the Office of the Provost. Mr. Orlen, Executive Officer of the Provost's Office, nurtured and managed the program for the past 10 years. Mr. Orlen was the first chairman of the IAP Administrative Committee and has most recently been serving as chairman of the IAP Planning Committee, whose membership includes all the departmental coordinators. This past May, Mr. Orlen left MIT to become vice president of the Science Museum of Minnesota.

In addition to Mr. Orlen's departure, IAP also lost the services of Ms. Sauer, who has been administrator of the IAP office for the past four years, as well as coordinator of the MIT-Wellesley Exchange Program. Ms. Sauer is taking a one-year leave of absence from MIT for educational reasons.

Mr. Orlen's responsibilities for IAP will now be shared by two staff members of the Provost's Office. Dr. Menand, Special Assistant to the Provost, will serve as chairman of the IAP Planning Committee and help oversee policy for IAP. Ms. Enterline, who has been editor of the *IAP Guide*, will supervise IAP operations in a newly created position, Manager of the IAP and MIT-Wellesley Exchange Program. A search is under way for people to fill the staff positions of Coordinator for IAP and the MIT-Wellesley Exchange and Editor of the *IAP Guides*.

MARY Z. ENTERLINE

Laboratory for Computer Science

The Laboratory for Computer Science (LCS) is an MIT 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 fields as engineering, architecture, mathematics, biology, medicine, library science, and management. Since that time, the Laboratory's objectives have expanded, leading to research across a broad front of activities that now span four principal areas.

The first such area, entitled Knowledge-Based Programs, involves making programs more intelligent by capturing, representing, and using knowledge which is specific to the problem domain. Examples are the use of expert medical knowledge for assistance in diagnosis 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 programs that comprehend typed natural-language (English) queries.

Research in the second area, entitled Machines, Languages, and Systems, strives to effect 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 research in the semantics of geographically distributed systems. Toward the same goal, the Real Time Systems group is exploring distributed operating systems and the architecture of single-user powerful computers that are interconnected by communication networks. Other research examples in this area include the study of data bases, and the architecture of very fast multiprocessor machines by the Computation Structures Research group, to link large numbers of otherwise autonomous computers.

The Laboratory's third principal area of research, Theory, 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 various classes of algorithms, the Semantics of Programming Languages from both analytical and synthetic viewpoints, the logic of programs, and the links between mathematics and the privacy/authentication of computer messages.

The fourth area of Laboratory research is entitled Computers and People and entails societal as well as technical aspects of the interrelationships between people and machines. Examples of research in this area include office automation research carried out by the similarly named research group; the use of interconnected computers for planning; as well as the social impact of computers on individuals and the ethical problems of distributed responsibility posed by multiprogrammer systems.

During the past year, the Laboratory consisted of 277 members -- 39 faculty, eight visiting faculty, 15 visitors, 90 professional and support staff, 85 graduate and 40 undergraduate students -- organized into 15 research groups. The academic affiliation of most of the faculty and students continues to be with the Department of Electrical Engineering and Computer Science. Other academic units represented in the Laboratory membership are Mathematics, Architecture, Division for Study and Research in Education, Humanities, and the Sloan School of Management. Laboratory research during 1979-80 was funded by 13 governmental and industrial organizations, of which the Advanced Research Projects Agency of the Department of Defense provided about half of the total research funds.

The 1979-80 year has been very active. Technical results were disseminated through the publications of the Laboratory members and will not be discussed here. The following items were highlights of the year.

During the reporting period, Professor Michael Hammer was appointed Associate Director of the Laboratory, joining Professor Albert Meyer who is also Associate Director of LCS. The need for two associate directors is the result of the Laboratory's rapid growth and increasing involvement with industry. Also during the reporting period Senior Research Scientist Albert Vezza was appointed coordinator of all LCS computational resources -- an action made necessary by the increasing number and diversity of our computers and associated equipment.

Professor Ronald Rivest has completed the design of a Very Large Scale Integration (VLSI) chip that implements the RSA (Rivest, Shamir, Adleman) data encryption algorithm developed by the Laboratory. To make this work possible, several VLSI design tools had to be developed, thereby launching LCS into a new area -- the development of design tools for VLSI and the architecture of special structures to be converted into VLSI circuitry. We expect this to be a major research theme for LCS for several years to come.

Our major Laboratory focus on geographically distributed systems has continued to occupy the attention of more than half of our staff. We have completed our design of a powerful personal computer than can employ different microprocessors as the technology of the latter progresses. This design was successfully transferred to Zenith Data Systems who delivered 10 engineering prototypes to us. In the coming year we expect to acquire a total of 150 such "advanced nodes" which we will use as direct research vehicles in some seven laboratory research groups, and as general tools for the office automation of LCS.

Our research in distributed computing can be viewed as a search for equilibrium between the opposing forces toward centralization and decentralization -- centralization since it maximizes order by vesting authority in one locus, and decentralization because of people's inherent need to control and use their own resources. We believe that increasing decentralization will have a significant effect on the field of computing in that: 1) it will make possible larger numbers of inter-communicating computational resources, and 2) it will permit acceptable operation of the aggregate system in spite of failures of local nodes.

During the reporting period, a new group called Systematic Programming was formed by Professor John Guttag. His research strives to establish a language in which program specifications can be effectively expressed, thereby improving the efficiency of large-program development. We expect that this group will grow during the coming year.

The Laboratory's Distinguished Lecturer Series, initiated in 1976, has proved very successful in attracting members of the MIT community. The 1979-80 lecturers under this series were: John McCarthy (Director, Artificial Intelligence Laboratory, Stanford University), Lawrence G. Roberts (Chairman, Telenet Communications Corporation), Kenneth E. Iverson (IBM Fellow, IBM Watson Research Center), Jacob Schwartz (Professor of Mathematics and Computer Science, Courant Institute of Mathematical Sciences, New York University), Brian Randell (Professor of Computing Science, Computer Laboratory, the University of Newcastle-on-Tyne), and Dana Scott (Professor of Mathematical Logic, University of Oxford).

During 1979-80, research in previously established areas yielded numerous new results which were published through Laboratory technical reports (TR219-TR239) and technical memoranda (TM138-TM167), as well as through articles in the technical literature.

MICHAEL L. DERTOUZOS

Laboratory for Information and Decision Systems

The primary goal of the Laboratory for Information and Decision Systems is to carry out basic and applied research in the general area of complex engineering and socio-technical systems. Research areas include theoretical development and selected applications involving the analysis and design of complex dynamic and stochastic systems and networks. This work requires the use of concepts from a variety of fields including system theory, decision analysis, communication and information theory, control theory, operations research, computer science, applied mathematics, and information systems technology.

The laboratory was founded in 1939 and played a major role in the development of Servomechanisms during World War II and the post-World War II period. Its name was changed from Servomechanisms Laboratory to Electronic Systems Laboratory (ESL) in 1959. Until March 1, 1978 ESL was a departmental laboratory in the Department of Electrical Engineering and Computer Science. On March 1, 1978 ESL was designated as an interdepartmental laboratory and now reports to the Office of the Provost. On September 20, 1978 its name was changed to Laboratory for Information and Decision Systems (LIDS) to more accurately reflect the research interests of its faculty, full-time research staff, and students.

The Director of LIDS is Professor Michael Athans, the Associate Director is Professor Robert G. Gallager, and the Assistant Director is Professor Alan S. Willsky; all three are members of the Department of Electrical Engineering and Computer Science. In the past year, 19 faculty members, eight visiting faculty, 14 full-time research staff, four visiting scientists, 15 support staff, and approximately 70 graduate and undergraduate students from several MIT departments have been affiliated with LIDS. Research support has been provided by the American Newspapers Publishers Association, the National Aeronautics and Space Administration, the Defense Advanced Research Projects Agency, the Department of Transportation, the Gannett Foundation, the Office of Naval Research, the Army Research Office, the Department of Energy, the National Science Foundation, the Air Force Office of Scientific Research, the Library of Congress, the National Library of Medicine, the General Motors Research Laboratories, the General Electric Company, and Systems Control, Inc.

In the past year the LIDS research budget exceeded \$2 million, and more than 100 new journal and conference articles and research reports were generated. A more detailed description of the research results can be found in the LIDS Annual Research Summary Report available from the LIDS publications office (Room 35-311).

RESEARCH

Systems, Estimation, and Control Theory

A major area of research deals with systems and control theory. The objectives of this effort are to provide a fundamental understanding of complex stochastic and dynamic systems, as motivated by several applications, and the development of methodologies, theories, and tools for their analysis and design. Significant advances in the state of the theory and design methodologies were made in the past year in the following research topics: 1) improved understanding of time-domain and frequency-domain approaches to multivariable control system synthesis; 2) novel results in the characterization of robustness of control systems performance to large parameter variations and unmodeled dynamics; 3) theory of stochastic and adaptive control based upon concepts of stability theory and dynamic optimization; 4) nonlinear estimation theory and random fields; 5) optimal control theory for distributed parameter systems described by partial differential equations; 6) estimation, control, and stability theory for systems with a hybrid state space that involve the dynamic interaction of continuous and discrete-valued state variables (event-driven systems); 7) fault-tolerant control systems and reliable control system synthesis methods,

including analytical redundancy techniques, failure monitoring, detection, and isolation algorithms; 8) microprocessor-based sampled-data control system issues, including the issues of finite word-length and computer architectures; 9) the theory of large-scale stochastic dynamic control systems under distributed control, including theoretical results on organizational, communications, and computational issues; 10) optimization algorithms for both static and dynamic optimization problems; and 11) dynamic game theory.

Many of the theoretical results in systems, estimation, and control have been used in more applied projects discussed in the sequel.

Communications Networks and Systems

A second major research area at LIDS deals with issues that arise in complex communications networks. This research is motivated by the increasing use of both civilian and military data communication networks (utilizing wire, fiber optics, and radio links) to transmit data or digitized voice messages. The objective of the research effort is to develop the necessary theory and distributed algorithms for the analysis and design methods for such networks. In the past year significant advances were made in the following research areas: 1) development of novel distributed quasistatic algorithms, involving only local computation at each node and nearest neighbor communications, for message routing; 2) combined routing and congestion control strategies; 3) multiaccess channel studies; 4) distributed routing algorithms for radio-packet networks with rapidly changing topology; 5) issues of queueing and flow control that arise in the transmission of digitized speech; and 6) special communication network issues that arise in distributed data based systems.

Command, Control, and Communications (C³) Systems

A third major research area deals with fundamental understanding of the complex issues that arise in military C³ systems. This represents a new area of research for LIDS, and was initiated to focus the research in systems and communications in the hope that a theory for C³ systems can be developed. Progress was made in the following areas: 1) the development of novel distributed detection and tracking algorithms of several objects by diverse sensors in the surveillance C³ subsystem; 2) control of distributed data base systems in a communication network environment subject to link and node failures; and 3) distributed decision theory, including organizational theory, to better understand what decision aids best serve the needs of a commander.

As an outgrowth of this research LIDS is sponsoring and organizing an annual two-week workshop on C³ systems. The second workshop was held in Monterey, CA, in July 1979 and the third workshop was held in Washington, DC in June 1980.

Transportation Systems

A wide variety of projects dealing with transportation-related problems are currently under investigation. These include: 1) studies of integrated radio communication and position location systems for urban vehicles; 2) air traffic control studies, with special emphasis on 4DRNAV; 3) transportation network optimization studies; 4) automotive engine and powertrain modeling and control studies; 5) improved control systems for chassis dynamometers; and 6) control strategies for automated guideway transit (AGT) systems.

Energy Systems

A diverse variety of research investigations have been carried out in the general area of energy systems. Progress has been made in the following areas: 1) multivariable control strategies for AC power networks using multiterminal DC links for power flow dynamic modulation; 2) fundamental understanding of stability issues in power networks so as to develop mathematical models and techniques to abstract severe phenomena such as blackouts and islanding; 3) power system effectiveness studies that include deterministic and stochastic representations of feasible loads, and the development of measures of effectiveness for the capability of a power system to supply service, taking into account reliability and costs; and 4) the development of a network model (ALINET) for analyzing energy use and evaluating specific energy-conserving technologies in the food processing industry, with special emphasis to wheat processing and pasta products.

Manufacturing Systems

The goal of this research effort is to develop relevant analysis and design tools for complex manufacturing systems, with special emphasis upon flexible manufacturing systems (FMS). Progress has been made in the following directions: 1) evaluation of production rates for small transfer lines as a function of buffer capacities, and machine failure and repair rates; and 2) routing and scheduling strategies in FMS machine networks, with emphasis upon the development of optimal and sub-optimal real-time control strategies.

Information Systems

Research in this area has continued along the following directions: 1) networking of interactive computer information-retrieval systems, and development of a computer interface to aid users to develop search strategies for bibliographical searches; 2) design of an electronic interlibrary resource sharing system; 3) a full-text transmission system that accepts microfiche images and transmits them to several copy stations with an eligibility of at least six-point type; and 4) studies of display terminals capable of time-sharing a television channel in cable TV systems.

Aerospace Systems

Several projects that deal with different aircraft problems are under investigation: 1) methods to compensate for vertical and horizontal wind shear effects in transport landings; 2) simulation of a control-configured F-16 aircraft to evaluate various display formats for better utilization of the aircraft's direct force control capabilities; and 3) reliable control strategies for landing a Vertical Short Takeoff and Landing (VSTOL) aircraft on the deck of a destroyer under high sea-state conditions.

Numerical Methods and Software

Basic research is continuing on the development of numerical methods and algorithms for solving generic problems in linear algebra, statistics, and control. These algorithms are implemented as robust mathematical software that is operational without modification on many different computing machines. Progress has been made in the area of robust statistical computing (dynamic determination of numerical rank, and iteratively reweighted least squares problems) and in robust computing for the solution of control problems. As an outgrowth of this research LIDS is sponsoring and organizing an annual two-week summer research conference on numerical and statistical computing; the first one was held in June 1980 at the University of Delaware Conference Center, Newark, Delaware.

MICHAEL ATHANS

Libraries

As the 1979-80 academic year drew to a close, the staff of the MIT Libraries undertook a review of the recent accomplishments, present state, and future needs of the library system through meetings of the Library Council and of departments and other organizational units. The confluence of a number of events seemed to make this a propitious time for such an analysis: the retirement of President Jerome B. Wiesner and Provost Walter A. Rosenblith; the appointment and impending appointment of several individuals to senior staff positions; the conclusion of five years under the present director of libraries; and the prospect of major decisions in several areas including bibliographic control, automation, space planning and allocation, and utilization of bibliographic networks. This report will attempt to cover some of the more significant aspects of the Libraries' operations in three segments: the changing nature of the Libraries during the past decade; the major events of the past academic year; and immediate and long-term goals.

Changing Nature of the MIT Libraries

The primary mission of the library system at MIT remains basically unchanged: to respond to the information needs of the MIT community by providing materials, information, and services within the framework of regional, national, and international cooperation. Accomplishing this goal, however, has required a significant number of new programs, definitions and redefinitions of policies and priorities, and administrative reorganization.

One of the most striking features of the changing nature of the MIT Libraries and of academic research libraries in general is the increasing degree to which these institutions have become mutually dependent for collections and services. As the cost of building and servicing research collections increases in terms of materials and salaries, the capacity to share these costs with other libraries becomes more and more important. One aspect of the evolution of the MIT Libraries is, therefore, the extent to which the Libraries have been able to extend both the quality and quantity of service through cooperative ventures. Among the major programs that have been initiated or extended in the past 10 years are the following: participation in shared cataloguing and interlibrary loan through OCLC and NELINET, the New England Library Information Network; reciprocal borrowing and expedited interlibrary loans with the Boston Library Consortium, Brown University, and Countway, McKay, Wolbach, and other units of the Harvard University Library; joint acquisition and staff development programs with the Boston Library Consortium; use of on-line bibliographic services where the costs are shared by a large number of libraries; and the joint Aga Khan Program for Islamic Architecture with the Fine Arts Library at Harvard.

A second major evolution, or perhaps even revolution, is the format of research library materials. The past decade has seen a tremendous growth in the number of microforms in the MIT Libraries, from about 200,000 in 1970 to almost 950,000 in 1980. This nearly five-fold increase may be contrasted with the Libraries' holdings of printed volumes, which have gone from 1.2 million to 1.8 million during the same period. There also has been a significant increase in the amount of other non-print materials such as slides, sound recordings, photographs, maps, and films. One effect of this shift has been more economical use of space; it has been necessary, however, to acquire and maintain reading and reproducing equipment, to train staff, and, not least significant, to educate users.

The research collections themselves have tended to change in a variety of ways. To serve strong research and teaching interests in science and engineering, increased emphasis has been placed on the serial literature. Despite several intensive periods during which subscriptions were surveyed and analyzed and less-used titles cancelled, the Libraries in 1980 subscribe to almost 4,000 more serials than they did 10 years ago. The rising cost of serials, which has far outstripped the general rate of inflation, has necessitated the diverting of funds from monographic acquisitions to serials, a trend that does not seem to be slowing down.

One of the most significant developments in the MIT Libraries has been in the area of collection development. With the impetus of the Collection Analysis Project, the Libraries have made a substantial change in collection policy, moving from department-centered to subject-centered collections. While this process has been complicated, expensive in staff time, and often difficult, there have been many positive effects, including better use of fiscal resources, a reduction in duplication, enhanced cooperation and communication among library units, and, in the long run, a set of collections more suited to the nature of teaching and research at MIT.

Another important development during the past few years has been in the area of archives and manuscripts. With the support of the Institute administration, the Libraries undertook a major effort to identify, collect, organize, and make available the official records of MIT. The appointment of a professional archivist, the receipt of a grant from the National Endowment for the Humanities, the establishment of a records management program, and the development of an access policy have all contributed to significant growth in collections and use. Concomitant with this has been greatly increased activity in the acquisition and processing of collections of personal papers of individuals who have been involved in the progress of science and technology both at the Institute and in associated organizations. The transfer of administrative responsibility for Historical Collections to the Libraries in 1977 made possible a further integration of activities associated with the documentation of MIT's history.

Libraries

The late 1970s saw a major change in the way in which research collections are physically dispersed at the Institute. Faced with the inevitability of a decentralized system because of space availability and limited funding for capital construction, the Libraries developed the concept of a Resource Sharing Center for less-used materials. While a permanent home for this operation remains to be found, a program of identification, weeding, and transfer was begun, and by the middle of 1980 almost 200,000 volumes were located in temporary facilities in Building N52. The program is being supported by a grant from the Booth Ferris Foundation.

A great deal of effort has been put into the area of staff development. Among the principal achievements have been the establishment of a Staff Review and Development Committee, a promotional system for librarians, a formal evaluation system, an increase in the use of staff committees and task forces, and the implementation of a travel policy that permits as many staff as possible to participate in professional meetings, seminars, and conferences.

The need to be more responsive to the changing nature and role of research libraries and to new policies and programs in the MIT Libraries has necessitated a number of organizational changes within the system. Most noteworthy among these have been the designation of the Associate Director as chief operating officer, the establishment of positions of Assistant Director for Public Services and Assistant Director for Administrative and Personnel Services, the appointment of a Collections Development Librarian, and the appointment of a Records Management Officer. A further reorganization of the collection development and technical services operations is described below under current activities.

THE YEAR IN REVIEW

The complete records of the Libraries' achievements during the past year are documented in the annual reports of the several departments and divisions, copies of which are maintained in the Director's Office. The following highlights are intended to provide an overview of some of the more unusual activities of the year. The real measure of how well the Libraries' mission is being carried out is evident in the ongoing functions of acquiring, processing, organizing, preserving, and delivering information. Every member of the staff contributed measurably to this end, and without their contributions the information needs of the MIT community could not be served effectively.

Cooperative Efforts

The first full year of the cooperative Aga Khan Program for Islamic Architecture with Harvard University saw the appointment of a bibliographer to the staff of the Rotch Library; the development of an acquisitions program; and considerable work on establishing mechanisms for acquisition, bibliographic control, and access between the two institutions. As the year ended, a joint Harvard-MIT committee was completing interviews aimed at the appointment of a librarian to direct the documentation aspects of the program.

Two other noteworthy cooperative ventures emerged during the year. One was the development of a reciprocal interlibrary loan system between the libraries of Brown University and MIT. Under this arrangement, requests from one library will receive preferential handling at the other, and charges for photocopies in lieu of loan will be eliminated. It is hoped that this program will be the first step in the increased cooperation that may be extended to cooperative acquisition programs in areas of mutual strength. The second development was the decision by the Board of Directors of the Boston Library Consortium to undertake a cooperative program for serial acquisitions and retention. Even if the proposal for a National Periodicals Center were to result in the establishment of such an entity, it is clear that the most significant benefits of cooperative activity in resource sharing are to be found at the local level.

Library Services

A major undertaking during the past year was the review and analysis of the Libraries' government documents collections. Material supplied by the US Government Printing Office to MIT as a

depository library represents a substantial amount of acquisitions on a regular basis. US documents are important research materials in almost every discipline that is served, and a review of how this material is selected, acquired, catalogued, and made available was long overdue. Under the leadership of the Collections Development Librarian, a task force completed a comprehensive study and produced a set of recommendations that have been adopted and are being implemented. Among the principal recommendations were 1) the adoption of the concept of a primary library responsible for collecting the publications of each issuing agency; 2) establishment of separate collections of government documents in each divisional and branch library; 3) review of all document series now being received; 4) establishment of a cataloguing procedure that utilizes the Government Printing Office cataloguing through OCLC; and 5) development of standardized forms and procedures for handling government documents within the MIT Libraries.

In the area of preservation, two developments took place during the year. The first was a change in binderies necessitated by the discontinuance of service by the Libraries' former binder in the Midwest. The binding was transferred to a local firm, Acme Bookbinding, and the results of this change, effected in October, have all been salutary. The quality of binding is consistently high, the turn-around time is four weeks or less, and the availability of preprinted forms has reduced processing time. The second accomplishment was improved in-house repair of materials. The volume of material in need of repair is increasing for a variety of reasons: binding of new acquisitions tends to be inferior; paper in books printed after 1850 is reaching the point of embrittlement; past repairs have been found to be faulty and have deteriorated; journals were often bound too thick and bindings are breaking; and staff are more aware than in the past of conservation needs. The hiring of a part-time consultant to implement recommendations made during the Collection Analysis Project resulted in the following: introduction of new materials; introduction of new procedures for paper repair, rebacking, tightening loose joints, and enclosures for brittle books; training sessions for library staff involved with binding and preservation; preparation of written guidelines for selection of materials to be repaired and for appropriate remedies.

The filming of the card catalogue representing the Libraries' acquisitions from 1861 through 1964 (the Dewey Decimal Catalogue) was begun during the year and will be completed in the fall of 1980. Results of this activity will be the availability on microfiche of a complete record of Dewey Decimal-classified holdings in all libraries and the release of much needed catalogue case space for expansion of the current catalogue.

The first full year of operation of the new Xerox 3100 copy machines has been most successful. The number of copies made on coin-operated machines increased by 40 percent, from 1.39 million in 1978-79 to 1.95 million in 1979-80. The machines proved to be considerably more reliable than those formerly used, and library patrons seemed genuinely pleased by the change. Three machines, to be located in the Hayden, Barker, and Dewey Libraries, will be added during the coming year. Another important addition of equipment was that of a Visualtek System installed in the Student Center Library for use by students with visual impairments.

Space and Facilities

The availability of space for the collections continued to be of great concern during the year. The Rotch Library, which is the most overcrowded of the major library units, reached the point beyond which no further materials could possibly be accommodated, and a major transfer of material to the Resource Sharing Center was undertaken. The Resource Sharing Center itself will be filled by the fall of 1980, but additional space in the present building has been promised. Additional space for the housing of Institute records as part of the Records Management Program was assigned to the Libraries in the building at 224 Albany Street.

In June, a display illustrating the history and development of the Institute was opened in the corridor leading to the Compton Gallery in Building 10. This facility and display were designed and mounted by the staff of Historical Collections with funds generously provided by the Class of 1917. Coincident with the beginning of the academic year 1980-81, responsibility for the operation of the Compton Gallery will be assigned to Historical Collections; the first exhibit mounted in this space under their administration is a collection of portraits and busts of MIT presidents that will remain in place through the forthcoming inauguration of Paul Gray in September 1980.

Staff Activities and Personnel Changes

Members of the staff continue to be involved in a wide range of professional activities at the institutional, local, regional, and national level. A complete record of all these is included in the archival version of this report.

A number of changes were made in the librarian staff during the year, several at the senior staff level. Susan J. Coté, formerly Assistant Director for Technical Services at Boston College, was appointed Associate Director of Libraries in March 1980, succeeding Margaret Otto, who moved to Hanover as Librarian of Dartmouth College. William J. Duggan, who served as Assistant Director for Administrative and Personnel Services, left the Libraries in December to become Assistant Comptroller of the Institute. His successor is Thomas L. Wilding, formerly Administrative Librarian of the Smithsonian Institution Libraries. Jutta R. Reed, Collections Development Librarian, has been appointed Director of Collection Development and Bibliographic Control in the Dartmouth College Library, effective September 1, 1980. Following an assessment of the current administrative structure of the Libraries, it was decided to create the new position of Assistant Director of Libraries for Collection Management, combining responsibility for collection development with administrative responsibility for the technical processes departments, Acquisitions and Catalogue. Clara-Mae Chittum was promoted from the Position of Acquisitions Librarian to Head of the Acquisitions Department as part of that reorganization. A full listing of staff personnel changes is contained in the archival version of this report.

As noted in last year's annual report, the MIT Libraries were to host a Council on Library Resources Management Intern during this past year. Rebecca Danforth Dixon, on leave from her position as Director of the Library at the Center for the Study of Youth Development in Boys Town, Nebraska, spent the year in the Libraries. She participated in a wide range of activities, working closely with the Director of Libraries, and had particular responsibility for the preparation of the Title II-C grant application and for editing a handbook for the librarian staff. This handbook has been compiled by the Staff Review and Development Committee and will be published in the fall of 1980.

The Libraries again sponsored a variety of programs during Independent Activities Period, including the fourth MIT College Bowl. Among the offerings were an exhibit of photographs of Boston from 1950 to the present; a self-paced course on calculus offered jointly with the Department of Urban Studies and Planning; the Chamber Music Marathon; lectures on children's literature; a seminar on locating corporate information; a panel discussion on ethical perspectives on the energy crisis; films about energy; a display illustrating the Libraries' resources connected with finding a job; consultation sessions on preservation; a course in T'ai Chi, the classical Chinese exercise system; a series of lectures entitled "What's New in the Humanities"; a life casting workshop; a display and demonstration on quilting; a series of three classic World War II films with discussions; a seminar on energy information sources; and the dedication of the Ellen Swallow Richards Lobby in Building 4.

The Corporation Visiting Committee for the Libraries met in April with the principal matters of discussion being bibliographic utilities, the Aga Khan Program, records management, and development. The Faculty Committee on the Library System met several times during the year, focusing their discussions on automation, collection development, and bibliographic control.

In the area of public services, the year saw a reorganization of the Libraries' committee structure in this area. The former Public Services Group, consisting of the heads of the divisional and branch libraries, was reconstituted with a steering committee consisting of the Assistant Director for Public Services and the heads of the five divisional libraries (Divisional Librarians Group). Four subcommittees were formed: Branch Librarians Group, Circulation Committee, Reference and Information Services Committee, and the Joint Committee on Technical Processing.

Gifts and Grants

A number of grant proposals were prepared during the year. A proposal to the National Endowment for the Humanities for support of the Boston Composers' Project was approved, and MIT will coordinate the completion of a computerized index of Boston musicians and their work that is being sponsored by the Boston Area Music Librarians. A request for operating support of Historical

Collections was submitted to the Institute for Museum Services. A Title II-C grant requesting support over two years for acquisitions and bibliographic control programs in the general area of science, technology, and society was submitted to the Office of Education but was not funded.

The Libraries continue to benefit from the generous support of a large number of individuals and organizations who provide both financial assistance and materials that add significantly to the strength of the collections. A complete list of individual donors is included in the archival version of this report. Among the major gifts during the year were a collection of 5,000 books and 11,000 reports in engineering and science from E.G.&G., Inc. (Edgerton, Germeshausen & Grier); collections of personal papers of David Baltimore, Bernard Feld, George Harrison, James Killian, Kevin Lynch, Calvin Mooers, John Sheehan, Richard Soderberg, Hans-Lukas Teuber, Victor Weisskopf, and Carroll Wilson; archival collections from the Department of Aeronautics and Astronautics, the Wright Brothers Wind Tunnel, the Bursar's Office, the Office of the President and Chancellor, the Servomechanisms Laboratory (now the Laboratory for Information and Decision Systems), and the Electronic Systems Laboratory. Historical Collections now has an outstanding collection of slide rules contributed by alumni and faculty in response to a request placed in *Technology Review*; Historical Collections also received a gift of laboratory equipment belonging to Morris Omansky, Class of 1911, given by his daughter Frieda Cohen. Late in the year the Libraries received a gift from Mr. and Mrs. Harold A. Traver establishing the Harold A. Traver, Class of 1932, Fund in electrical engineering.

Future Concerns

Although the Libraries' review of program priorities mentioned at the beginning of this report is still in progress, it is clear at this point that several areas must be addressed both in terms of immediate decisions and long-range planning. Listed below in abbreviated form and in no particular order of priority are some of the major challenges that face the MIT Libraries in the years ahead:

Automation. Application of available systems to circulation, serials control, and acquisitions.

Bibliographic Utilities. Utilization of existing networks for additional services such as an on-line catalogue, public service terminals, retrospective conversion.

Bibliographic Control. Implementation of AACR 2 (Anglo-American Cataloguing Rules) including training of technical services and public services staffs and users.

Technical Reports. Further integration of the acquisition, cataloguing, storage, and servicing of these materials into existing and future systems.

Staff Development. Review of committee structure and staff participation. Improving communication within the library system. Orientation for new staff.

Facilities. Additional space for Rotch Library. Permanent location for Resource Sharing Center. Improving the quality of existing facilities. Establishment of a media center.

Extension of use of on-line searching of bibliographic data bases as part of reference services.

Further development of the concept of subject-oriented collection development as enunciated in the Collection Analysis Project report.

The challenge of the future for the Libraries is clear: to maintain a high level of quality in collections and services; to adapt to the changing environment within and outside the Institute through the intelligent application of intellectual and material resources; and to seek new means for improving the process by which information is transferred from creator to consumer.

JAY K. LUCKER

Lowell Institute School

The Lowell Institute School (LIS) was established at the Massachusetts Institute of Technology 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 degree or equivalent experience.

The programs of study range from single subjects designed to broaden job skill levels to comprehensive study of new technological areas in preparation for employment in a new field. There is a strong emphasis on practical aspects and development of careful experimental technique combined with sufficient theory to provide an adequate foundation of understanding. Certificates are awarded to those who satisfactorily complete a course. In addition, special certificates are awarded to students who complete a program of courses in the fields of Drafting Technology and Electronics Technology.

During 1979-80, LIS offered 24 evening courses in the fall term and 27 in the spring term. The fields of instruction included Analog and Digital Electronics, Microprocessors, Applied Mathematics, Mechanical and Electrical Drafting, Fundamentals of Quality Assurance, High Speed and Creative Photography, Machine Tool Fundamentals, Principles of Metal Joining, Printed Circuit Board Design, Scientific Glassblowing, and Welding Qualifications and Testing. In addition, new courses were introduced in Advanced Printed Circuit Board Design, Architectural and Pictorial Drafting, Communications Systems, and Energy Alternatives.

LIS continued to offer intensive one-week daytime courses for individuals working in industry. Two one-week courses in Microprocessors were offered in cooperation with the Boston Section of the Institute of Electrical and Electronics Engineers, and a one-week course in Digital Electronics was conducted specifically for CBS Television Network technicians.

For the third consecutive year, a 12-week Machine Tool Training Program was organized and conducted by LIS in cooperation with the Departments of Mechanical Engineering and Materials Science and Engineering under the Comprehensive Employment and Training Act (CETA), a Federally funded program designed to teach employment skills to disadvantaged and hard-core unemployed persons. By making facilities available for this CETA program, MIT contributes an important social service to Cambridge residents. During the past year, all students who completed the program gained employment as machinists or machinist-trainees.

LIS admitted a total of 1,040 students to its courses in 1979-80, 984 to the evening classes and 56 to the intensive daytime courses. Of those who enrolled, 76 percent successfully completed the certificate requirements. Among those who completed courses were 30 MIT employees and two regular MIT students. Ten students earned the special certificate in Electronics Technology, and one student earned the special certificate in Drafting Technology. In order to qualify for these special certificates, a student must complete a specified program of study.

The past academic year has seen LIS expand its program of unique evening courses which no other Boston area school can match. Enrollment has increased for the seventh straight year, and the high percentage of students who successfully complete their courses indicates that both the subjects offered and the level of instruction are well matched to their needs.

BRUCE D. WEDLOCK

Neurosciences Research Program

The Neurosciences Research Program (NRP) is an international, interuniversity, and multidisciplinary organization operating as an off-campus MIT Research Center. 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 transform 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 world-wide 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 NRP Associates to provide advice and guidance to a small professional staff at the NRP Center in Boston, Massachusetts. NRP also enlists participation in its activities by 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 1979-80: "Electrophysiological Approaches to Human Cognitive Processing" (R. Galambos and S.A. Hillyard); "The Cytoskeleton and the Architecture of Nervous Systems" (R.J. Lasek and M.J. Shelanski); "Mechanisms of Selective Signaling by Calcium" (R.H. Kretsinger); "Signal Transduction Across Cellular Membranes" (J.-P. Changeux); "Excitatory Neurotoxins: Selectivity, Specificity, and Mechanisms of Action" (J.T. Coyle).

The emphasis of the scientific program during this year shifted toward problems of more complex and global aspects of neural function ("higher brain function"). Highlighting this new direction were the scientific programs given at the fall 1979 and spring 1980 Stated Meetings of NRP Associates. In October 1979, under the chairmanship of F. Plum and R.Y. Moore, a program was presented on "Brain Aging-Dementia," examined at all levels from molecular neurobiology to clinical neuropsychology. A report of this was published in the *Newsletter* of the Society for Neuroscience (March 1980). At the spring Stated Meeting, March 1980, under the chairmanship of E.R. Kandel, a program on "Analysis of Behavior" treated the topic at levels ranging from cellular and biophysical determinants through neurophysiological and behavioral levels to theoretical considerations, and extending across research on invertebrates and vertebrates.

In spring 1980, the following were elected to be Associates of NRP: F.H.C. Crick, J.B. Martin, and P. Rakic.

The F.O. Schmitt Medal and Lectureship

A feature of the spring Stated Meeting of NRP Associates was the Seventh F.O. Schmitt Lecture in Neuroscience given at MIT in Room 10-250. The 1980 medalist, Dr. Louis Sokoloff, National Institute of Mental Health, gave an address entitled "The Relationship Between Function and Energy Metabolism: Its Use in the Localization of Functional Activity in the Nervous System."

During the academic year the following *NRP Bulletins* were published: *Cellular Mechanisms in the Selection and Modulation of Behavior*, E.R. Kandel, F.B. Krasne, F. Strumwasser, and J.W. Truman; *The Brainstem Core: Sensorimotor Integration and Behavioral State Control*, J.A. Hobson and A.B. Scheibel; *Dynamics of the Brain Cell Microenvironment*, C. Nicholson; *Visual-Vestibular Interactions in Motion Detection*, V. Henn, L. Young, and B. Cohen.

Reorganization Plans

In preparation for the 1980s, NRP initiated this year a reorganization of its scientific goals, leadership, and modes of action.

During the past 18 years, NRP has been influential in the forging of a worldwide neuroscience community. This has been so successful that many earlier functions of NRP are now being fulfilled by numerous national and international professional organizations. Rapidly evolving changes in neuroscience require adaptive changes in NRP, and after several years of intensive study by NRP Associates, it was decided that the unique resources of NRP should be shifted from a broad and general attention to neuroscience to a more selective focus on experimental, technological, and theoretical problems in research on more complex aspects of neural function. A basis for attacking higher levels and more global aspects of neural function was established during the 1970s with the rapid acquisition of new knowledge about simpler levels of neural function (morphological, neurophysiological, and chemical). Clearly, much remains to be learned about the simpler levels of neural function, but research at these levels is proceeding rapidly within the worldwide neuroscience community, whereas the extraordinary challenge of research on the more global aspects of neural function suggests a particular opportunity for the catalytic influence of NRP to provide impetus for progress toward this emerging new level of neuroscience.

The proposal for these new scientific goals was ratified on September 17, 1979, by an ad hoc committee of Associates (W.M. Cowan, G.M. Edelman, E.V. Evarts, J.J. Hopfield, S.S. Kety, and V.B. Mountcastle). G.M. Edelman was invited to accept the newly created position of Scientific Chairman of NRP, to provide additional leadership which is so critically important for the new directions. At his request, a new Scientific Advisory Committee (SAC) was appointed, chaired by W.M. Cowan and consisting of F.E. Bloom, E.V. Evarts, J.J. Hopfield, S.S. Kety, V.B. Mountcastle, and W.E. Reichardt.

These new goals and leadership were reviewed, discussed, and endorsed by Associates at the 38th Stated Meeting of NRP Associates (October 14-17, 1979). Subsequently, these plans were further developed in meetings of SAC on January 12, 1980, and March 16, 1980, and at the spring Stated Meeting of Associates (March 16-19, 1980).

The essential features of the newly emerging NRP are a leadership structure consisting of the Director (F.G. Worden), the Scientific Chairman (G.M. Edelman), and SAC (chaired by W.M. Cowan). A new modality will be inserted into the existing NRP structure to intensify the attack on higher and more complex levels of neural function. This will have the form of a "mini-institute" providing live-in facilities for up to six eminent scientists to come together for short periods (two weeks to several months) of daily, intensive interaction on a specific problem defined by them in advance. This new institute will supplement the existing NRP apparatus, interacting with it to enhance its capacity for intensive problem-oriented attack on higher-order problems that transcend the currently established approaches in neuroscience research.

By March 1980, it had become increasingly clear that consideration should be given to moving NRP from Brandegee House to the campus of Rockefeller University (RU) because of the following reasons: as Scientific Chairman, Dr. Edelman's leadership role would be much more effective if NRP were located at Rockefeller University near his own research laboratories; the relative isolation of Brandegee House from academic activities (e.g., teaching, research, library services, computers) was judged to be less favorable than an on-campus location, especially for the proposed Neurosciences Institute; and fund-raising prospects were judged to be substantially better from a base in New York than from one in Boston.

In view of these considerations, NRP Associates at the March 1980 Stated Meeting authorized Dr. Edelman to explore the possibility of moving NRP to RU. Progress in this direction was surprisingly rapid; the administration of RU has enthusiastically endorsed making NRP an on-campus activity and providing necessary backup, including offices, housing for scientists, and assistance in NRP's fund-raising programs.

Tentatively, it is planned to initiate a pilot study of the Neurosciences Institute on the RU campus in the summer of 1981. NRP would continue to function at Brandegee House, moving to RU in 1982.

FREDERIC G. WORDEN

Northeast Radio Observatory Corporation Haystack Observatory

The Northeast Radio Observatory Corporation (NEROC), is a consortium of 13 institutions* formed in 1967 to promote radio and radar astronomy research and facilities in the northeastern United States. NEROC receives financial support for its principal facility, MIT's Haystack Observatory, from the National Science Foundation (NSF) and project support from NSF, the National Aeronautics and Space Administration (NASA), and other Federal agencies, and it uses the administrative services of MIT in the conduct of its business. Observing proposals submitted by prospective users are considered by a review committee, on the basis of scientific merit and suitability for the available instrumentation.

The main instrument at the Observatory, located at Westford, Massachusetts, is a 120-foot diameter paraboloidal antenna enclosed in a radome. It is heavily used by the astronomy community as a radio telescope with radiometers in the 18-, 13-, 6-, 3.8-, 3-, 2-, 1.35-, 1.07-, and 0.7-cm regions. The Haystack telescope constitutes an important astronomical resource, particularly in the wavelength region 1.5-0.7 cm, which lies between the shortest wavelengths covered by most of the larger telescopes and the longest wavelengths at which the smaller, true millimeter-wave instruments are most profitably used. At 0.7 cm, the telescope has a beamwidth smaller than the 1-arc-minute resolution of the human eye.

In the past year, the telescope was used by approximately 100 investigators from more than 20 different institutions, and 50 articles were published in scientific journals based upon this work. Approximately 20 percent of the telescope usage was by MIT faculty and their students.

Very long baseline interferometer (VLBI) research and development continued as a leading in-house activity at Haystack. The VLBI technique involves simultaneous observations of the same object with widely separated radio telescopes; records of these observations are subsequently brought together in a correlation processor to yield interferometer fringes. For astrometry and studies of complex source structure, VLBI provides resolution not attainable by any other means. With support from NASA, better methods are being developed for applying VLBI techniques to precise geodetic as well as astronomical measurements. Under this program a new data acquisition and processing system called Mark III has been developed to provide a five-fold increase in sensitivity over past systems. Copies of this system are now being built for several other observatories collaborating in this work.

Geodetic VLBI measurements are now being made between Haystack, the 40-meter telescope at Owens Valley Radio Observatory, California; the 43-meter telescope of the National Radio Astronomy Observatory in Green Bank, West Virginia; the 26-meter telescope of the Harvard College Radio Observatory in Fort Davis, Texas; the 100-meter telescope of the Max Planck Institute in Bonn, Germany; and the 20-meter telescope of the Chalmers Institute of Technology in Onsala, Sweden. These measurements are designed to test the stability of the tectonic plates and to measure the motion between them. The measurements using the new Mark III system have centimeter level accuracy, and one of the baselines (Haystack-Owens Valley) has been measured long enough (76-80) to establish that the drift rate across the North American plate is less than 1 cm/year. The intercontinental drift rate between North America and Europe should be established in a few years. The full sensitivity of the Mark III has been used in VLBI observations

*Boston University, Brandeis University, Brown University, Dartmouth College, Harvard University, MIT, Polytechnic Institute of New York, Smithsonian Astrophysical Observatory, State University of New York at Buffalo, State University of New York at Stony Brook, University of Massachusetts, University of New Hampshire, and Yale University.

of weak compact radio sources in nearby galaxies and to study objects like the "double" quasar 0957+56. VLBI observations of 0957+56 using the 100-meter Bonn telescope and the NASA 64-meter telescope at Goldstone, California have been used to measure the angular separation of the two components (which are probably images of a single quasar split by the gravitation field of an intervening galaxy) to better than 50 millionths of a second of arc. A search for an additional compact radio source close to 0957+56 has been made to flux levels below 1 milliJansky.

Single antenna programs by visiting scientists tend to emphasize spectral-line studies using the shorter wavelength receivers and the 1000-channel digital correlation spectrometer. Interesting examples of this include the detection of the rare long chain molecule HC₅N at 24 GHz in two dark cloud regions and studies of the unusual dynamics and physical properties of the galactic center by means of observations of the J,K=3,3 transition of NH₃ and high frequency recombination lines of hydrogen.

A new receiving system for 6 cm wavelength observations has been completed and improvements made to the performance of the 0.7 cm radiometer. Work is underway to construct a second liquid-helium-cooled maser to extend the present coverage (1.4 to 1.2 cm) down to 1.05 cm wavelength.

On 1 January 1980 Dr. John V. Evans succeeded Paul Sebring as the Director of Haystack. Mr. Sebring, who had been the Director since 1970 when Haystack was placed under the control of NEROC, was an outstanding administrator who guided the Observatory through a difficult and trying period. Dr. Evans was also appointed Professor in the Department of Meteorology and Physical Oceanography. He comes to us from the Lincoln Laboratory, where he is an Assistant Director with responsibility for programs in advanced electronics - a position he will retain.

J. V. EVANS

Office of Minority Education

The Office of Minority Education (OME) has carried out a number of programs and activities described below in its mission to assist minority students, expand the educational resources open to them, and increase the number of minority students who graduate successfully. During the past year, Professor Arthur C. Smith has served as acting director. Pearline Davidson Miller has been the assistant director.

The Office also provides a center for student activity and informed support to students. It has been very capably staffed by Gloria Payne, administrative assistant, and Mireille Desrosiers, secretary, and has profited from the services of several student staff members.

As in previous years, OME has had the counsel of a faculty-staff-student advisory group. This year a separate student advisory group was formed under the chairmanship of Gwendolyn Wise.

The search for a director of OME has continued. On his return to MIT in February, Professor Wesley L. Harris became chairman of the committee to advise the Associate Provost in this search.

Project Interphase

Project Interphase fills an important role for a selected group of entering minority first-year students. The program provides academic preparation and orientation to life at the Institute.

The number of students participating in Project Interphase 1980 was 48, compared with 51 in 1979, 41 in 1978, and 33 in 1977. Mrs. Miller had the responsibility for overall direction of the program. Professor Alan Davison supervised the academic content of the program as he has done for several years.

The basic structure of the program has been the same for a number of years, focusing on rigorous academic preparation in chemistry, humanities, mathematics, and physics. A formal introduction to the resources of the Institute and to general academic skills was also provided. Group athletic and social activities were planned for students and staff. Tutors for the program lived in the dormitory with the students and were thus able to provide effective assistance and support.

Black Student Union Tutorial Program

The Black Student Union Tutorial Program continued to provide tutorial assistance to undergraduates. In 1979-80, the program provided more than 4,700 hours of tutoring in 60 subjects. The tutors are graduate students and upperclass undergraduates; their services are coordinated by student coordinators and program secretaries under the general supervision of Mrs. Miller. The student coordinators were Laura-Lee Davidson, Rosemarie Wesson, and Geoffrey Holman.

The Freshman Buddy System continued this year as part of the tutorial program, and was coordinated by Janice Antoine. Upperclass students serve as "buddies" to several assigned first-year students and are expected to contact them weekly to offer friendly support and give guidance in the use of Institute services.

The use of videotape for tutor training and as an aid to tutors in a specific subject was a new feature this past year. The initial evaluation of this activity was quite positive and further use of videotape is planned.

Videotaped Instruction

In past years, lectures in some first-year core subjects were videotaped. Selected groups of students viewed the tapes with a tutor who offered explanations or answered questions. Students found it difficult on occasion to attend the sessions regularly due to unforeseen academic requirements on their time. During the past year, a different use was made of videotaped lectures which seemed to be more successful.

A team of tutors in the BSU Tutorial Program who were tutoring 5.41 Introduction to Structure, Bonding, and Mechanism, reviewed the tapes of each week's lectures. Selected portions were used in tutoring sessions when dealing with material which needed a visual presentation. The videotapes thus served to keep the tutors aware of the current status of the subject and helped them anticipate difficulties; the tapes also served as another tutoring resource to supplement notes and texts. This use of tapes appealed to both tutors and students, and student performance in 5.41 was improved over previous years.

The team of tutors undertook a project during the Independent Activities Period to condense and index the taped lectures so that they would be more easily used next year. Similar condensing of taped 8.02 Physics II lectures was also begun.

This use of tapes is still in an experimental stage and will continue to be modified as further experience is gained.

Freshman Watch

Freshman Watch is an academic counseling program operated by OME with the cooperation of the faculty and staff teaching science requirement subjects. Information is supplied to OME at mid-term regarding performance of minority students in these subjects. Students who are having difficulty are asked to come to the Office for counseling and tutorial assistance. This program supplements the activities of the freshman advisor and communication with each advisor is maintained.

Second Summer Program

The Second Summer Program was offered for the second time in 1980. This program combines work in industry with an on-campus academic program, and was offered to selected students upon completion of their freshman year. Nine students worked for 10 weeks at one of the

Operations Research Center

cooperating companies: E.I. du Pont de Nemours & Company, Goodyear Tire & Rubber Company, and Monsanto Company. The two-week academic program focused on problem-solving techniques and practice in mathematics and engineering. In addition, sessions on academic planning, communication skills, getting started in research, and evaluation of the work experience were held.

Activities

During the year, OME has sponsored a number of seminars and assisted students in planning various activities. These included: R/O Week activities in cooperation with the Black Student Union; seminars on time management and academic planning; sponsorship of a student-produced videotape about minority student life at MIT; an IAP seminar to prepare students for the Medical College Admission Test; seminars on interview techniques, resume writing, and employer expectations; sponsorship of student representatives to attend national conventions of professional societies; and assistance in the formation of a chapter of the Mexican American Student Association.

Awards and Gifts

OME selected James D. Oliver to receive the Monsanto Achievement Award as the third-year engineering student with the best academic record. The award consists of a plaque and a \$500 prize given by Monsanto Company to promote academic excellence among minority engineering students at MIT.

OME received gifts to further activities aimed at increasing the number of graduating minority engineering students from E.I. du Pont de Nemours & Company, Bethlehem Steel Company, and Goodyear Tire & Rubber Company.

ARTHUR C. SMITH

Operations Research Center

The Operations Research Center (ORC) conducts interdepartmental academic and research programs in the field of operations research. The academic staff of the Center is drawn from the Sloan School of Management and the Departments of Electrical Engineering and Computer Science, Urban Studies and Planning, Aeronautics and Astronautics, Civil Engineering, Mechanical Engineering, Ocean Engineering, Mathematics, and Physics. At present, approximately 20 students are in the operations research doctoral program and a comparable number are in the master's program. Most of them come to MIT specifically to study operations research and are admitted directly by the Center, although some learn about the graduate operations research program by attending seminars or subjects.

During the past year, the academic staff of the Center was engaged in an expanded range of basic and applied research sponsored directly by the Center and, in part, by other laboratories at MIT. Basic research was carried out in the areas of mathematical programming, optimization, network or graph theory, and statistics. Applied research projects included those in energy systems, transportation systems, urban systems, operations management, public program evaluation, and criminal justice systems.

Significant progress continued this year on applying operations research to problems of transportation systems. Earlier work on setting traffic signals has been extended; a portable computer program, called MAXBAND, now determines signal settings for an artery or triangular network so as to maximize the green band available to traffic on an artery. In demand-responsive transportation systems, a dynamic programming algorithm developed recently for a single-vehicle immediate-request dial-a-ride problem has been extended to the multi-vehicle case. The multi-vehicle algorithm allows several origin and destination points for customers; it can examine two principal categories of objective functions, has vehicle capacity constraints and special priority

rules to prevent indefinite deferment of customer requests. The transportation work also included new analyses of equilibrium models of urban transportation networks. This work predicts traffic flow on each network link allowing for multiple modes of transit, link interactions, general customer disutilities for travel, and travel-time-dependent demand rates between origin-destination pairs. The analysis invokes Brouwer's fixed point theorem and recent advances in mathematical programming.

Work continued on the merging of location theory with probabilistic processes. The definition of optimal locations (medians) of a transportation network has been successfully extended to the case in which travel times on network links are random variables with known discrete probability distributions. Under reasonable assumptions, it was shown that well-known "facilities at nodes" theories can be extended to such stochastic networks.

Building on recently completed work on finding minimal distance paths in the presence of barriers to travel, new results have been obtained for optimally locating a given number of facilities so as to minimize mean travel time of customers. Here travel is assumed to take place according to the rectilinear (or right-angle or "Manhattan") distance metric, barriers are given polygons (representing parks, cemeteries, rivers), and customers are distributed arbitrarily over a finite number of demand points. It is shown that an optimal set of facility locations can be drawn from a finite set of candidate points, all of which are easy to determine.

Progress has continued in the modeling and analysis of spatially distributed queuing systems. A new model, which is a generalization of the "hypercube model" developed at the ORC several years ago, predicts the performance of an N-server, zero-line capacity queuing system in which servers accommodate two types of customers: those that are centrally assigned by a "dispatcher" and those that are "discovered" by individual servers. The computer-implemented approximation procedure for the model, which accurately depicts police patrol operations, requires solution to only N nonlinear equation rather than 3^N associated with the corresponding exact model.

Research was completed on an empirical study of 200 criminal justice evaluations. The research pointed out the needs for more complete documentation of the inputs, processes, and outcomes of an evaluation. It was found that little is known about the decision consequences of an evaluation, yet it is the improvement of decision making that motivates most evaluations. The research pointed to the need for new evaluation methodologies, including Bayesian and model-based techniques. Papers demonstrating the utility of such approaches were produced as part of the study.

Research also was completed on a statistical analysis of various problems in criminal justice. Analyses focused on recent trends in urban homicide, the deterrent effect of capital punishment, and predictive modeling of robberies and burglaries.

ORC staff produced new reports and findings in statistical research, particularly multivariate linear and nonlinear regression. One effort focused on the development of a computer program that generates diagnostics for the user of regression models, thereby making it easier for him or her to identify influential data and sources of colinearity. Another effort showed how the lack of careful use of regression in public policy situations -- such as studying the effect of capital punishment on murder rates -- can lead to erroneous or, at best, unfounded policy conclusions.

Work continued on the construction and analysis of energy-planning models combining mathematical programming and econometric methodologies. Research was completed on the implementation of a model of US coal supply and demand markets and its use in selected policy studies. Mathematical programming decomposition theory permitted the integration and efficient optimization of statistical models of coal supply, coal transportation models, and electric utility capacity expansion models. A separate project was begun to integrate an energy sector process model with an econometric model of energy end-use demands. The integrated model is being optimized according to several criteria to see which criterion produces optimal (equilibrium) prices and quantities that are closest to those historically observed.

Considerable work occurred this past year in the area of production management and strategic planning for industrial firms. This work ranged from documented case studies (in which the introduction of a formal strategic planning system in a business firm is described), to new models

related to production and inventory management, to rigorous mathematical analyses of advanced production planning systems. Much of the mathematical work focused on hierarchical production planning. Initially, the basic trade-offs inherent to production planning decisions are represented by means of an aggregate model, which is solved on a rolling horizon basis; subsequently, the first solution of the aggregate plan is disaggregated considering additional cost objectives and detailed demand constraints. Special attention was given to alternative disaggregation procedures, problems of infeasibilities, and the treatment of high setup costs. Additional work in hierarchical production planning focused on the introduction of feedback into the planning system; this work involved a decomposition of a mixed-integer linear program.

Scheduling problems received attention by ORC staff members. This work ranged from a review of production scheduling techniques to new mathematical methods for scheduling when schedules must repeat periodically over time. For instance, with cyclic scheduling one must size and schedule a minimum cost workforce so that sufficient workers are on duty during each time period. Modeling this as an integer linear program with a cyclically structured 0-1 constraint matrix, one can solve the problem by using a series of related network flow problems.

Much of the ORC research contributed to graph and network theory. One example is recent work in dynamic network flows, in which flow is to be routed over time through a network having bounds on the feasible amounts of flow in each arc and a flow time associated with each arc. The objective is to minimize the average cost per period of sending flow.

The ORC maintained its intense research interests in mathematical programming (i.e., optimization theory). On the practical side, this year ORC staff members completed the implementation of a large-scale, interactive system for linear programming (SESAME) and mixed integer programming (SESAMIP). These systems are now available for use at MIT's Information Processing Center. They are replacing earlier software systems provided by the hardware manufacturer.

In advances to the theory of mathematical programming, significant progress was made in such areas as inverse optimization, decomposition techniques, problem formulations for programs and combinatorial optimization techniques, computational complexity, equilibrium models, convex programming, multiple objective optimization, duality theory, and linear fractional programming. For instance, inverse optimization is a new approach to the parametric analysis of discrete optimization problems such as plant location, vehicle routing, and multi-item production/inventory control. Multiple objective optimization seeks to discover the full range of policy options available to a decision maker when attempting to allocate resources and simultaneously achieve different (often conflicting) goals. An example would be the location of facilities, in which the multiple objectives include reduction of customer travel times, increasing profitability, and balancing of workloads among facilities. As a final example, the theory of computational complexity seeks to determine how much "work" a computer must do to solve a given mathematical problem; much emphasis here is on the development of algorithms that require the least work, in the sense of minimizing the number of computer operations required to solve the problem.

RICHARD C. LARSON
JEREMY F. SHAPIRO

ROTC Programs

Enrollment in the Reserve Officer Training Corps (ROTC) programs continued at the high level of recent years. A total of 364 MIT students were enrolled in our three ROTC detachments, a slight drop from the peak enrollment of 385 MIT students in the preceding year. However, the presence of an additional 121 students from Harvard, Northeastern, and Tufts universities, and Wellesley College raised the total enrollment in our units to 485 students, the highest level in recent years. These additional students receive instruction from the MIT Army and Air Force instructional staffs under separate institutional cross-enrollment agreements and are included administratively in the MIT ROTC units.

The distribution of enrollments was as follows:

<u>SERVICE</u>	<u>YEAR</u>				<u>Total</u>
	<u>I</u>	<u>II</u>	<u>III</u>	<u>IV</u>	
Army	52	30	29	21	132*
Navy	48	47	25	22	142
Air Force	<u>81</u>	<u>67</u>	<u>36</u>	<u>27</u>	<u>211**</u>
Total	181	144	90	70	485

* Includes 52 cross-enrolled students [Wellesley (9), Tufts (23), Harvard (20)].

** Includes 69 cross-enrolled students [Wellesley (10), Tufts (5), Harvard (18), Northeastern (36)].

In addition to their regular programs of instruction and training, the ROTC detachments engaged in several special events during the past year. Two of these events were particularly impressive and are noted here. In May more than 300 cadets and midshipmen participated in an impressive Pass in Review Parade in Steinbrenner Stadium. This was the first such combined parade event in many years. Reviewing officer for the parade was MIT's Provost, Dr. Walter A. Rosenblith. The annual commissioning ceremony in June was especially noteworthy because of its being held on the flight deck of the aircraft carrier *USS John F. Kennedy*, which was in Boston to participate in the city's 350th anniversary celebration.

The ROTC Faculty Advisory Committee continued its role in reviewing the operation of the detachments and of officer assignments to MIT. The latter function is particularly important in guaranteeing that personnel assigned to MIT possess the academic and leadership qualities appropriate to this unique institution. The Committee was pleased to recommend the appointment of Commander Michael Wojdyla to be the incoming Executive Officer of the Navy ROTC unit at the conclusion of the academic year. Commander Wojdyla replaces Commander Kenneth B. Russell who is retiring from the Navy. The Committee also reviewed and approved the appointments of Lieutenants Michael J. Maynard and Thomas S. Charis to the Navy unit, Captain Frederick K. Arzt, Jr. to the Air Force unit, and Captains Richard C. Oertel and Thomas D. Bortner to the Army unit.

During the past year the Committee recommended the establishment of an agreement with Harvard University which would permit cross-enrollment of their students in the MIT Navy ROTC unit, starting in September 1980. This recommendation was made in response to a change in Navy policy which now permits such cross-enrollments for nonscholarship students. The Committee also took the position that a similar arrangement with Wellesley students automatically exists because of the existing agreements under the Wellesley-MIT Exchange Program.

The Committee reexamined the issue of academic credit for ROTC subjects and again affirmed its earlier position that academic credit should be granted only for those subjects that are offered through regular academic channels. In general, this precludes the granting of credit for ROTC subjects, except those that are offered as a part of regular academic department or division offerings.

FRANK E. PERKINS

Sea Grant College Program

The academic year 1979-80 marks MIT's 10th year of participation in the National Sea Grant College Program. For the past decade MIT Sea Grant has helped the citizens of the nation and of the Commonwealth of Massachusetts to discover and exploit the ocean's potential wisely and efficiently. The MIT Sea Grant Program's major activity is sponsoring marine-related research in more than 10 departments and centers in the Institute. The research results have been directly applied to solving problems in the marine community.

To disseminate the research and to translate the results for different constituencies, the MIT Sea Grant Program supports an advisory service, which includes the Marine Industry Advisory Service (MIDAS), the Massachusetts Marine Liaison Service (MML), and the Marine Communication/Information Service. MIT Sea Grant's educational effort is concerned with training the professional and "marine-literate" population to utilize MIT research results and to make informed choices on marine, ocean, and coastal issues.

An endowment from the Henry L. and Grace Doherty Charitable Foundation encourages non-tenured MIT faculty to focus their research on contemporary problems in the marine field. During their two-year appointments, Doherty professors remain affiliated with their respective academic departments, but conduct their research under the aegis of the MIT Sea Grant Program.

Dean A. Horn directs the Program and works with the Sea Grant Director of Research, Professor Jerome J. Connor of the Department of Civil Engineering, and with the Associate Director for Education and Coordination, Ernst R. Pariser, to formulate long-range perspectives and evaluate Program proposals and progress.

The advisory service managers are Arthur B. Clifton, Norman Doelling, and Elizabeth T. Harding. The Program's daily operation is managed by Administrative Officer Lawrence W. McKinnon.

Two outside committees assist Sea Grant in formulating policy and evaluating project proposals. They are the State-Industry Advisory Committee, chaired by Edward Brainard, President of Environmental Devices Corporation, and the Sea Grant Program Committee, chaired by Professor Emeritus Alfred A. H. Keil.

A Sea Grant Program Review Committee was established this past year by the Provost to evaluate MIT Sea Grant and to offer recommendations to further strengthen and improve operations and increase the value of the Program to the MIT and Massachusetts communities. The Committee Report endorsed Sea Grant's operations, accomplishments, and objectives; it recommended, however, that communication between the Program and the MIT faculty be improved.

ADVISORY SERVICES

The three components of Sea Grant's Advisory Service, the MML, MIDAS, and the Marine Communications/Information Service, may be characterized as the technology transfer arm of the Program. Tailored to the needs of the Massachusetts community, advisory services provide information and assistance to state and local agencies, marine businesses, and industry -- as well as the interested public. They also provide a "feedback loop" through which problems and opportunities as seen by user communities may be communicated to program administrators and researchers at MIT.

MIDAS, created in 1975 under the leadership of Mr. Doelling, continues to foster the partnership of MIT Sea Grant faculty with business and government through a Collegium. Through quarterly workshops and research reports Collegium members are able to discuss significant business opportunities and applications emerging from research at MIT and other universities.

Workshops this past year at MIT included "Some Federally Funded Research Programs for Unmanned Underwater Vehicles," which reviewed research and development being carried out in this field; "A New Underwater Communications System," which examined the acoustical telemetry research for underwater systems; and "Nondestructive Evaluation of Fiber Composites," which discussed research important to the recreational boating industry. In April, a meeting was held in conjunction with the Sea Grant Program at Louisiana State University on the protection of materials in the marine environment, specifically anti-fouling coatings for ships, offshore structures, and pilings. The addition of John Bidwell to the Sea Grant staff has helped MIDAS to add 20 new members to the Collegium, increasing the total membership from 88 to 114.

Under the guidance of MIDAS, MIT Sea Grant originated a national newsletter, "Research in Ocean Engineering: University Sources and Resources." This newsletter, co-sponsored in 1979-80 by the National Oceanographic and Atmospheric Administration (NOAA) Office of Ocean Engineering, reports on current ongoing marine research at MIT and at universities throughout the United States.

The Massachusetts Marine Liaison Service, managed by Mr. Clifton, is the service through which the Sea Grant Program and the Institute are able to offer specialized help and support directly to local Massachusetts and New England industries.

MML's most dramatic contribution this past year was the introduction of a successful prototype spiny dogfish skinning machine developed to exploit a large European market for this fish resource. Food processing machinery companies have been reluctant to invest in the development of this type of machine because of technical difficulties and high financial risk. However, it is this kind of high risk technology development that is one of Sea Grant's unique charges. MML is playing a critical role in seeing that this skinning machine, developed by Professor David Gordon Wilson in the Department of Mechanical Engineering, is effectively transferred to a manufacturing company which will make it available to fish processors throughout the areas in the US where the dogfish can be found. On March 31, 1980, a special demonstration was held by MML to introduce the dogfish machine to manufacturers, fish processors, and fishermen. A videotape made of the machine's operation was made to show interested manufacturers from all over the country how it works.

MML has cooperated with industry on a number of projects to develop technologies promising greater economic and safety benefits to the fishing and maritime communities. Among these are a side trawl hook-up block, and steel-streamlined trawl doors. The hook-up block was designed to take the place of a dangerous and antiquated device that is used today to secure net cables to the stern of a fishing boat so that it can maneuver while towing the net. The MIT Sea Grant block, a double acting, snap-on device, is released remotely and safely. The Coast Guard has installed a modified version of the new hook-up block on its cutter *Alert* to hoist lifeboats. This device, after extensive testing, may be installed on all the fishing patrol cutters. The steel-streamlined trawl doors, developed several years ago at MIT, have now been fully refined and are commercially available.

The Extension Sea Grant Advisory Service (ESGAP) facilitates cooperation between MML and the Massachusetts Cooperative Extension Service to disseminate marine information to coastal communities. Among ESGAP's projects this past year was a conference on designing small-craft marinas and harbors, a growing problem for many of New England's communities.

MML is working jointly with the Massachusetts Maritime Academy at Buzzards Bay to support a Marine Fisheries Training Program. They will continue to make available additional fisheries training programs through the Cape Cod Community College, Essex Agricultural College, the Massachusetts Division of Marine Fisheries, and the New England Marine Fisheries Steering Committee.

MML also manages the MIT research vessel *Edgerton*, a floating laboratory available for use by Sea Grant investigators, other MIT researchers, and industrial researchers working in the marine field.

The third part of the Advisory Service, the Communications/Information Service, managed by Ms. Harding, published 31 technical reports in 1979 which transmitted results of Sea Grant research to various industry, government, and academic groups. The *MIT Sea Grant Quarterly Report* was established as the regular news bulletin for MIT Sea Grant marine research and educational

activities. Each summer issue announces the Program's research projects for the coming academic year and provides a thumbnail sketch of all current projects, while each subsequent issue explores three of them in depth. The *Quarterly Report* also includes abstracts of recently published Sea Grant reports. This service is also experimenting with MIT's Educational Video Resources Service (EVR) to develop videotapes which can be used to effectively transmit research results. Communications/Information maintains a small reference facility for the general public.

EDUCATIONAL EFFORTS

The National Sea Grant College Act and Program of 1966 specifies education and training as an essential part of the Sea Grant Program. A broad spectrum of activities at MIT encourages awareness of marine and aquatic issues and problems. The educational component of the MIT Sea Grant Program, under the direction of Dr. Pariser, focuses on curriculum development efforts at MIT to give students education and training in the marine field.

In the Department of Ocean Engineering under the guidance of Dr. Ira Dyer, Sea Grant is supporting an Ocean Engineering Project Laboratory to give undergraduate and graduate students an opportunity to develop new marine technologies, including automated underwater welding, gas content analysers, special instrumentation and underwater television equipment. Special summer courses for public education, offered in cooperation with the Sea Grant Program and the Summer Session, provided research results as well as reflected the efforts of Sea Grant projects.

Educational projects outside of the MIT community involved helping the New Bedford public school system develop teaching modules to introduce marine science into elementary and high school curricula. Interested MIT faculty members have been asked to help evaluate these modules. The project has the endorsement and support of the Massachusetts Department of Education and has earned for New Bedford a Title IV-C education grant to expand this effort and build on the activities developed by Sea Grant.

At the college level, Sea Grant has organized an inter-institutional consortium to jointly develop and offer an introductory course in marine affairs. This course, "Into the Ocean World," introduces the student to the many disciplines that involve the sea: maritime history, marine sciences, marine politics and economics, marine arts and literature. Eighteen colleges and universities in the greater Boston area have participated in, or provided matching funds to support, this new course.

Each year the annual Sea Grant Lecture reviews current problems and introduces future perspectives. This past year the Lecture, "Understanding the Oceans: Motivating Today's Youth to Work for Tomorrow," was delivered by Dr. Herman G. Branson, President of Lincoln University and a member of the MIT Corporation. Lecture panelists included Dr. James W. Mayo, Scientific Advisor, US Department of Energy; Dr. Mary P. Rowe, Special Assistant to the President and Chancellor for Women and Work, MIT; Logan Sallada, Policy Analyst, President's Reorganization Project, and Captain Roderick M. White, Dean of Academics, US Coast Guard Academy. Dr. Pariser served as moderator for the discussion.

RESEARCH

Sea Grant funds a broad spectrum of research at MIT involving investigators from many different departments. Two years ago the Program identified five major themes and organized the Program's research into the following areas: Coastal Processes, Coastal Zone Development, Living Resource Development, Technology for Ocean Uses, Unmanned Underwater Work Vehicles, and Offshore Facilities.

The first thematic area, Coastal Processes, is concerned with natural physical processes in the marine environment created by human activities in the coastal zone.

On the island of Martha's Vineyard, planners are concerned with the threat of seawater encroachment and contamination of their limited freshwater supplies. To help communities like this one, Professor John L. Wilson III of the Department of Civil Engineering has created a Sea Water Intrusion Model (SWIM) to allow coastal planners to model regional freshwater flows under various development options.

Coastal salt marshes could be made more productive through fertilization with nitrogen-rich effluent; but before altering the marine environment, the consequences of change must be understood. In the Department of Civil Engineering, Professors Harold F. Hemond and Keith D. Stolzenbach are working with John Teal of Woods Hole Oceanographic Institution to learn how nutrients with potential pollutants are distributed through a salt marsh. The model, which estimates the tidal transport and dispersal of dissolved substances, is generally applicable to many salt marshes using a minimum of site-specific data.

Sea Grant's Coastal Ecology research considers the biological aspects of the marine environment. For example, Professor Alician V. Quinlan, a Doherty Professor from the Department of Mechanical Engineering, is coordinating a multidisciplinary team of students and faculty from MIT, the University of Massachusetts, and Northeastern University to understand and overcome the brown algae pollution that affects Nahant Bay beaches every summer. Their approach involves chemical and circulatory analysis of the bay water, biological analysis of the algae itself, and examination of the changing environmental conditions which can affect the accumulation of algae. The researchers have received matching funds from the Metropolitan District Commission's Division of Environmental Quality Engineering.

Dr. Morteza Janghorbani of MIT's Nuclear Reactor Laboratory and Dr. Guy C. McLeod, Director of Research at the New England Aquarium, are experimenting with sewage effluents to grow phytoplankton, brine shrimp, and juvenile fish. They are evaluating the trace elements uptake in species which have been fed on various combinations of sludge treated by conventional methods and by high energy electron bombardment, and comparing this to the normal uptake from sea water.

A critical coastal resource at the base of the food chain is eelgrass, *Zostera marina*. Professor Eugene Bell of the Department of Biology currently is investigating to see if the slime mold *Labrynthula* is responsible for the periodic decline of this plant.

Professor Sallie W. Chisholm of the Department of Civil Engineering is studying the physiology of New England's red tide organism, *Gonyaulax tamarensis*, to reveal which features of this organism allow it to bloom, making shellfish poisonous for human consumption. Over the past year, Professor Chisholm and several research assistants have isolated and cultured several species of phytoplankton from Perch Pond in Massachusetts, a site where red tides have appeared in recent years. By comparing photosynthetic physiology of the various algae, the MIT scientists hope to understand how to predict blooms and ultimately control them.

In the research area of Coastal Zone Development, Professor Judith T. Kildow of the Department of Ocean Engineering is leading a research team of faculty and students to examine management strategies for the Boston Harbor. The project team is interacting with the Massachusetts legislature to provide the data and recommendations which will lead to the coordinated development of Boston's urban waterfront. This project is jointly supported by Sea Grant, the Office of Coastal Zone Management, Massachusetts Port Authority, Boston Shippers Association, and the state legislature.

Two projects in the Living Resource Development thematic area involve the study of chitin, a long chain polymer similar to cellulose, found in the wastes of crab, shrimp, lobster, fungi, and plankton. Professor Benjamin L. Averbach in the Department of Materials Science and Engineering has been perfecting ways to extract chitosan from chitin. This derivative shows promise for removing contaminants from polluted waters. Because chitosan films have near zero permeability, they also show excellent potential for replacing petrochemical products as food wrappings.

Another application of chitin is as a matrix from which to engineer or fabricate food. A chitosan matrix, developed by Professor Cho Kyun Rha of the Department of Nutrition and Food Science, will permit scientists and food engineers to use protein extracts, minced fish flesh, and both natural and synthetic flavors to duplicate natural food forms. It is hoped that this research will

promote the utilization of unused species of fish, crustaceans, and edible waste now lost by standard fish processing techniques.

Sea Grant's Offshore Facilities research focuses on the design and maintenance of offshore structures to counteract geotechnical instabilities and harsh weather conditions. Professor T. William Lambe and Research Associate W. Allen Marr of the Department of Civil Engineering are developing a computational procedure to predict the permanent displacement of the foundations of offshore gravity structures that result from cyclic loading by waves. The procedures which result from this research will benefit the offshore industry as well as government regulatory agencies responsible for assessing the long-term safety of proposed or existing offshore facilities.

In the same department, new techniques and analytical methods to determine soil properties directly at offshore sites are being developed. In cooperation with an international geotechnical consulting firm and the Venezuelan Petroleum Technological Institute, Professors Charles C. Ladd and Mohsen M. Baligh have investigated the use of two devices that combine simplicity, consistency, and economy. One, the Dutch cone, estimates the undrained shear strength of clays and strength and compressibility characteristics of sands. The other, a piezometer, identifies soil types and evaluates soil stratification. The researchers hope to combine the two devices into one instrument to replace costly and time-consuming core drilling procedures now being used to study subsea soils.

Unmanned Underwater Work Vehicles interest Sea Grant because of their potential for construction and maintenance of offshore structures at depths where divers cannot go. At MIT, Professor Thomas B. Sheridan of the Department of Mechanical Engineering is continuing his development of a mechanical telemanipulator with all-purpose arms, hands, and tactile sensors to perform deep-sea tasks. Laboratory tests conducted this past year have revealed to researchers what combination of human and computer control the manipulator needs to complete a variety of tasks under severe communication restraints.

In the Department of Ocean Engineering, Professor A. Douglas Carmichael is working on the development of a second-generation search-and-survey underwater vehicle. Robot II is a smaller, lighter, faster, more stable vehicle than its predecessor and is equipped with an array of sonar for communicating information on the seabed.

Professor Arthur B. Baggeroer of the Departments of Ocean Engineering and Electrical Engineering and Computer Science is conducting research to overcome some of the difficulties underwater vehicles have in receiving and sending messages through the highly reverberative, non-homogenous marine environment. He and his associates from MIT and Woods Hole are using microprocessing to transform digital instruction into tones which then are relayed in chords. The results of this research will eliminate cumbersome tethers and communication cables now needed for remote vehicle communication.

Professor J.D. Nyhart and Doherty Professor Harilaos Psaraffis of the Department of Ocean Engineering are leading an MIT faculty and student team effort to develop a deterministic model incorporating alternative strategies for cleaning up medium- to small-sized oil spills. The project evolved from one of Sea Grant's Collegium workshops and is supported by an advisory committee composed of representatives from government and industry. The research team also hopes to develop an optimization model to locate existing emergency clean-up equipment for small-scale oil spills.

MIT researchers believe that heavily contaminated harbor dredge spoils could be processed to recover reusable heavy metals and to produce clean sand and clay products. Water, brought to near-critical temperature and pressure levels, shows promise as a solvent for separating potentially valuable products. Chemical Engineering Department Professor Michael Modell will be testing the technical feasibility of this hypothesis using carbon and heavy metal-laden sediment samples taken from the polluted Boston and New Bedford harbors. In the second stage of this exploratory research project, studies will compare the costs of the new reprocessing method with current regulated dumping practices.

Doherty Professor Francis Noblesse of the Department of Ocean Engineering continues to evaluate his wave resistance theory for ships, which is based on Brard's work, the Neumann-Kelvin theory.

He is applying his analytical technique to two specific idealized hulls -- a wedge-like bow and a parabolic strut -- and to arbitrary ship hull forms. This research will help to minimize drag in ships.

A research project which may have direct benefits for boating manufacturers and recreational boaters is one conducted by Professor James H. Williams, Jr., of the Department of Mechanical Engineering. He has been experimenting with blended liquid crystals, painted on a fiberglass boat hull and heated to controlled temperatures, to create color patterns that essentially map the structure. The colors change through a spectrum, spreading uniformly as the heat intensifies. Deformities resist and deflect the heat and show up in an irregular configuration revealing potential flaws like cracks or delaminations. Professor Williams will apply his one-dimensional theoretical model to select appropriate crystal combinations and heat sources for mapping fiberglass laminates of even and uneven thickness. He will be turning this process into a kit which may be used to detect flaws in fiberglass boats before they go to sea.

Professor Koichi Masubuchi of the Department of Ocean Engineering is perfecting and testing an electromagnetic underwater flux-shielded arc welding unit. This simple, watertight system, operated by push button controls, will produce more reliable welds on deep ocean structures.

Aluminum heat exchangers, to be used on ocean thermal energy conversion (OTEC) plants, must last at least 10 years to be economically feasible. This will require study into maximum corrosion resistance of aluminum in natural salt water. With a grant from the Sloan Basic Research Fund, the MIT Sea Grant Program is supporting Professor Ronald M. Latanision's research on the effects of copper and other heavy metal ions on the initiation of pits in aluminum in natural salt water. Although the most direct application of this research is to OTEC, it is useful in understanding the corrosion behavior of aluminum in areas with high copper concentrations, occurring either naturally or due to the presence of large amounts of anti-fouling coatings.

Sea Grant-sponsored research projects are varied and often multidisciplinary to meet the complex needs of an ever-changing marine community. The involvement of MIT's diverse, talented faculty and students, with government support, allows the Institute to participate in a national effort to develop new marine resources and preserve existing ones.

DEAN A. HORN

Summer Session

Special Programs

The Summer Session Office administers an extensive series of one- and two-week Special Programs for professional men and women who wish to keep pace with developments in their fields. This activity has prospered each summer since its initiation in 1950.

Of the 65 programs planned for the 1979 session, only one was cancelled because of a projected low enrollment. The total registration of 1,888 in 1979 was an increase over the 1,782 in 1978.

The Special Summer Programs have widespread appeal. Sixty percent of the registrants had addresses east of the Mississippi. However, there was a significant foreign contingent with seven percent from Canada and 16 percent from other foreign countries. A noticeable trend in the composition of the student body has been the slow but steady increase in the number of women registrants. They comprised 10 percent of the 1979 class as compared with only three percent in the late 1960s. The one characteristic of the registrant body which has remained remarkably constant is that the average age of a registrant is 37.

Regular Subjects

Graduate students comprise 80 percent of the student body in summer. The 1979 registration of 2,610 students was an increase over the 2,344 in 1978.

JAMES M. AUSTIN

Technology Adaptation Program

The Technology Adaptation Program (TAP) is an interdisciplinary research program with the primary objective of promoting an awareness of and an expertise in the technological problems facing the developing countries on the part of faculty and students at MIT, as well as foreign students and scholars who attend MIT. This objective is met by encouraging faculty participation in specific, well-defined research projects with faculty collaborators from academic institutions in certain developing countries. In addition to the research projects, TAP has conducted a wide range of academic activities including: development of informal institutional ties between MIT and foreign universities, research institutions, and government organizations in developing countries; educational opportunities at MIT for those interested in issues of technology and development, such as interdisciplinary master's degree programs, graduate research assistantships, and visits by foreign scholars; conferences, workshops, and seminars; and dissemination of information through publication of technical reports, working papers, and proceedings of its conferences.

ORGANIZATION

The Technology Adaptation Program is organized according to the following principles:

- 1) The program relates to those research activities for which there exists faculty support and faculty willingness to participate. The program does not undertake research projects which require large-scale non-faculty staffing. The research activities are supervised and conducted by faculty members, and are administered through their respective home departments.
- 2) The Program committees are composed of MIT faculty members, and the Program Director is a faculty member, thus maintaining academic quality control not only in the conduct of research and educational obligations, but also in the selection of topics for research and the institutions with which the Program develops educational ties.
- 3) The Program's activities are carefully scrutinized by appropriate Institute committees such as the Committee on International Institutional Commitments. The Institute is consulted in the early stages of negotiations on all potential sources of funding, including public and private sources both in the US and abroad.

In accordance with the above principles TAP is organized with the following basic components:

- The Program Director, Professor Fred Moavenzadeh of the Department of Civil Engineering, is responsible for the coordination of all resources utilized for the Program.
- The TAP Policy Committee is chaired by Professor Nazli Choucri of the Department of Political Science (who is also Associate Director of the Program). Committee members are Professor Daniel M. Holland of the Sloan School of Management and Professor Jack Ruina of the Department of Electrical Engineering and Computer Science. Professor Moavenzadeh serves in an ex officio capacity.

- Technology Adaptation Program Advisory Committee, composed of the Deans of the Schools and chaired by the Provost, is responsible for overseeing TAP activities and advising on Institute policies and administrative procedures. Professors Choucri and Moavenzadeh serve as ex officio members.

Jeanne De Pass is the Program's Administrative Officer and Kevin O'Toole serves as Technical Officer. James H. McCarthy is the resident Administrative Officer of the MIT/Cairo University Liaison Office in Cairo.

TECHNOLOGICAL PLANNING PROGRAM IN EGYPT

In December 1976 the Agency for International Development (AID) entered into a contract with MIT to establish a collaborative research effort with Cairo University and various ministries of the government of Egypt to improve their capabilities in analyzing, planning, and managing important Egyptian developmental programs, and to study the feasibility of institutionalizing the process by establishing a research center at Cairo University. The means by which the general objectives are pursued is through cooperation with the faculty of Cairo University in developing capabilities to contribute to the formulation and implementation of science- and technology-related policies designed to assist Egypt's developmental goals. To this end, three specific objectives have been pursued: 1) mobilization of academic interest in research on specific development plans; 2) organization of technical research in collaboration with Egyptian government ministries; and 3) establishment of an institutional framework in Egypt through which permanent research and training capability can be organized.

The specific research projects organized so far employ three general analytic approaches: 1) engineering analysis and technical project evaluation, addressing specifically technical issues, including field and laboratory studies, design, and training requirements; 2) economic analysis, focusing on project, sector, and national planning issues, and micro- and macroeconomic studies related to specific Egyptian development programs; and 3) social science analysis of population and labor force issues, socioeconomic change including urbanization, extension of social services, technology transfer, and strategies.

Since 1976, 14 collaborative projects have been developed between MIT faculty members and their counterparts at Cairo University and the appropriate ministry or government agencies in Egypt. They focus on a broad range of engineering, economic, and social science topics, as described below. The key element in each of these efforts is the interdisciplinary team drawn from faculty and staff from MIT, Cairo University, and government ministry personnel responsible for planning development projects in the topic area. Effective mobilization of the Egyptian academic and government resources has been one of the principal reasons for the success of the program to date. In addition to the research activities, emphasis has been placed on the training of in-country personnel in the techniques of project identification, evaluation, and management, and the development and maintenance of the data necessary to design and monitor their projects.

RESEARCH PROJECTS

The research projects have focused principally in four broad areas: 1) energy, including electricity generation and distribution; 2) manufacturing, including small-scale industries, plastics and building materials; 3) public works, including housing, transportation, and water resources; and 4) socioeconomic development, including population migration, health care delivery, economic planning, and rural communications.

Energy

Long Term Investment Planning for the Egyptian Electric Power System. The objective of this project is to help develop professional skills in applying tools of mathematical economics and operations research to analyze project alternatives for Egyptians concerned with planning electric

power projects. This project is under the direction of Professor Martin Weitzman of the Department of Economics and Professor James Kirtley of the Department of Electrical Engineering and Computer Science.

Manufacturing

Engineering Applications for the Plastics Industry. The objective of this project is to develop a capability at Cairo University and in several private and public companies that will support the ministries' plans to broaden the applications for plastics. The project is under the direction of Professor Frederick J. McGarry of the Department of Materials Science and Engineering.

Public Works

Housing and Construction Industry. The objective of the project is to develop the technical and economic knowledge and tools needed in the determination of national housing policies. Specific recommendations are intended to be developed with focus on investment policies, controls and regulations, provision of services, and other government intervention in housing. The project's goal is to assist the Egyptian government in developing a housing policy which will better enable the various supply institutions to meet the country's housing needs. This project is under direction of Professor N. John Habraken, Head, Department of Architecture. Professors Albert G.H. Dietz and Eric Dluhosch of the Department of Architecture and Professor William C. Wheaton of the Department of Economics and Urban Studies and Planning are also participating in this project.

Innecity Transportation Planning. The objective of the project is to develop a methodology that will make possible the systematic analysis of future transportation investment policy proposals in Egypt. The methodology, which addresses both intercity freight and intercity passenger movements on highways, railways, and inland waterways, will complement previous transportation planning efforts in Egypt. This program is under the direction of Professor Moavenzadeh. Research Associates Michael J. Markow, Brian Brademeyer, and Frederick Salvucci in the Department of Civil Engineering are contributing to this project.

Urban Transportation. The objective of the Urban Transportation project is to assist the Transport Planning Authority and other agencies in strengthening their project implementation and policy-making processes in the area of urban transportation. This project is under the direction of Professors Nigel Wilson and Michael Meyer of the Department of Civil Engineering. Professor Ralph A. Gakenheimer of the Department of Urban Studies and Planning continued his interest and contributions to this project while on sabbatical leave.

Regional Groundwater Studies. The objective of this project is to develop computer models for the Nile Delta Aquifer and the Nubian Sandstone Aquifer to assist in evaluating the aquifers' safe yield, their capability to act as a storage reservoir, and their interaction with irrigation and drainage activities. This project is under the direction of Professor John L. Wilson of the Department of Civil Engineering.

Stochastic Model of the Nile Inflows to Lake Nasser. The objectives of this project are: 1) to develop computer-based stochastic simulation models which represent Nile River stream flows for use in planning of the water resources systems; 2) to model the hydrologic behavior of the Nile swamp to allow prediction of the water yield taking account of uncertainty; and 3) to develop forecasting models for use in reservoir and irrigation systems operations. This project is under the direction of Professors Rafael Bras and Peter S. Eagleson, both of the Department of Civil Engineering.

Water Resource Planning Models for the Nile River Basin. The objective of this project is to identify and evaluate alternative water resource development plans and their economic, physical, and social impact. This project is under the direction of Professor David H. Marks of the Department of Civil Engineering.

Performance of Paraffinic Asphalt-Cements in Egyptian Road Construction. The objective of this project is to evaluate the properties of the Egyptian waxy asphalt cements and to improve the performance of Egyptian pavements constructed by means of these asphalts. The project is under the direction of Professor Mohsen Baligh of the Department of Civil Engineering. Research Associate Amr Azzouz of the same department is also contributing to this project.

Socioeconomic Development

Communications Needs for Rural Development. The objective here is to assess the needs of Egyptian villages for communications facilities, and suggest means of using communications technologies to improve the economy and society of the villages. This program is under the direction of Professor Ithiel de Sola Pool of the Department of Political Science.

Egyptian Labor Migration. The objective of the project is to contribute to an understanding of the costs and benefits to Egypt of the migration of labor to other Arab countries. The intent is to provide a set of consistent data on labor migration and on the socioeconomic variables that are related to the migration process. Such an assessment will be useful to the relevant ministries for a comprehensive view of the structure and impacts of migration on the Egyptian economy. Indication of the implications for sector-specific concerns will also be visible. The project is under the direction of Professor Nazli Choucri of the Department of Political Science.

Health Care Delivery Systems. The objective of this project is to provide appropriate ministries with recommendations on ways to improve the delivery of public health services. Focus is on the organizational management responsibilities of the ministry rather than on specific hardware needed to upgrade the system. This project is under the direction of Professor Richard Eckaus of the Department of Economics. Dr. John O. Field, Research Associate in the Center for International Studies, is taking major responsibilities in this project.

Improved Methods for Macroeconomic and Sectoral Planning. The objective of the project is to develop and apply improved methods for overall sectoral policy making. The methods are used to analyze relatively quickly, yet comprehensively, the consequences of alternative proposals such that policy makers are provided with more effective means than heretofore have existed of formulating economic policy with a better appreciation of its consequences. This project is under the direction of Professor Eckaus. Professor Lance Taylor of the Department of Economics is also participating.

DEVELOPMENT RESEARCH & TECHNOLOGICAL PLANNING CENTER AT CAIRO UNIVERSITY

As part of the institutional efforts of the program in Egypt, MIT provided assistance and support aimed at establishing a permanent institutional mechanism to facilitate and promote academic research directed toward developmental goals of Egypt. In early 1979 the Development Research and Technological Planning Center (DRTPC) was established, and a Director and a Board of Directors were appointed. The Board of Directors includes four representatives from the faculty and administrative staff of Cairo University plus three senior members from government.

A set of research and training objectives and an administrative structure for the Center have been implemented. The by-laws of the Center contain the following list of objectives:

- To provide a technical research base and to help train Egyptian government cadres involved in planning and implementation of development projects.
- To improve academic capabilities in Egypt in order to apply research for the analysis and solution of development problems.
- To create a permanent framework, through which to direct applied research and training capacity in order to solve development problems and to adapt technology for development purposes.

- To provide methods for analyzing programs of economic, social, and technical development with the help of associated institutions.
- To provide technical consultation to the Egyptian government ministries in identifying and modeling development problems and devise applicable solution programs.
- To train Egyptians at associated institutions abroad.
- To organize conferences, symposia, and meetings, as consistent with the above objectives.

In order to continue its activities on a self-sustaining basis the Center has identified five major sources of potential support:

- 1) Provision of grants by Egyptian government organizations for general training and administrative activities.
- 2) Grants from Egyptian government organizations for coordinated research contracts with Egyptian institutions.
- 3) Direct research contracts with Egyptian institutions.
- 4) Direct research contracts with foreign institutions.
- 5) Grants or endowments from international organizations.

To date six grants totaling over 350,000 Egyptian pounds (approximately \$500,000) have been received from Egyptian organizations covering the first two sources listed above, and four contracts have been received totaling about 120,000 Egyptian pounds (approximately \$170,000). In the future, strong efforts will be made to diversify into funding from the last two sources, as well as to increase the levels provided by the first three.

In terms of implementing its research program, the Center has established or is developing more than 30 projects, including those sponsored by outside grants and contracts and those undertaken within the Center itself. Over 100 Cairo University faculty and staff members participate and are compensated in this research, and mechanisms for providing administrative support and compensation have been established.

EDUCATIONAL OPPORTUNITIES

TAP has expanded educational opportunities at both MIT and in Egypt. Opportunities for learning have been made available for both faculty and students interested in general or specific topics related to transfer and adaptation of technology, and valuable experience on specific, real problems has been gained. The projects have provided an opportunity for future decision makers to serve as apprentices under experts in particular areas of technical and economic development.

Some of the more specific educational opportunities offered during the past year include those outlined below.

Research Assistantships. The number of graduate research assistantships offered by the program has shown a steady growth since its initiation in 1976. At that time a total of 14 research assistantships were granted. This year a total of 41 were in effect. The experience working on these projects has provided the basis for theses at both the Ph.D. and Master's degree level at MIT and Cairo University.

Curriculum and Subject Development. Although no funds were available during the first phase of the program for development of new subjects, several faculty members have incorporated material from their project work into regular subjects taught during the academic year. The second phase of the project is expected to provide funds for course development.

Visits by Foreign Scholars. To date more than 100 Egyptian participants from Cairo University and various government agencies have visited MIT. Some have attended short courses on specific topics, while others have followed more informal programs designed to increase their awareness of current developments in their fields.

Travel by MIT Staff. MIT faculty, staff, and students spent a total of four person-years in Egypt during the past year. Several staff members were also able to visit other locations overseas to meet with experts working on similar development problems, or to attend conferences relevant to project research. In addition to the TAP research and administrative staff, James Culliton, Director of Personnel and Robert J. Long of the Comptroller's Accounting Office, traveled to Cairo to assist in the operation of the Liaison Office. During the next phase of the contract, it is anticipated that other MIT administrative staff may be asked to travel to Cairo to provide program assistance.

Conferences, Workshops, and Seminars

The program normally holds at least one major conference in Cairo each year. By so doing the participants have the opportunity to present the results of their research efforts to their peers and to those personnel working in the field, primarily from the government ministries, who may not be aware of the state-of-the-art of the research being conducted in Cairo. During the first phase of the program more than 1,250 people have attended the various workshops, seminars, and conferences sponsored by the program.

In the past year a major conference was held in January at Cairo University. It presented an opportunity for all principal investigators to discuss the technical aspects of their projects. All MIT principal investigators, research staff, and students who worked on the projects were in attendance for the three-day meeting.

Two other seminars were held in Cairo during the past year. The Housing and Construction Industry project conducted a seminar in Core Housing attended by key government and industry personnel. A two-week workshop in Construction Management was also held.

EVALUATION OF THE PROGRAM

During spring 1980 the Egyptian program underwent an in-depth evaluation of its activities. The evaluation team was comprised of two retired AID division directors and a former university president. The group interviewed more than 90 personnel in Washington, MIT, and Cairo which included a two-week period in Egypt and two separate visits to MIT. The evaluators found considerable evidence that the research teams formed in the program have produced results which are being incorporated by the Egyptian Government, and that attitudes and skills have shown a marked improvement of both Cairo University faculty and in key ministries. The team strongly recommended that the program be continued for an additional three years. In their final report the team also recommended that the base of involvement of personnel be expanded and that more formal training be added. In response to these recommendations the program intends to add new initiatives for the new contract period, which is expected to begin in October 1980 for a three-year period. These initiatives are in addition to the research project concept which proved effective in the past and include the following:

- 1) Undertake a series of mini-research projects of three to six months' duration with emphasis on increasing Cairo University capabilities, which can lead to the development of long-term contracts with the government ministries.
- 2) Provide support to junior faculty members at Cairo University in postdoctoral research. This effort will involve course work at MIT and associations with MIT faculty members.
- 3) Provide financial incentives for graduate student theses in areas of relevance to the development goals of Egypt.

Upward Bound Program

- 4) MIT faculty participation in course development at Cairo University.
- 5) Development of short course "packages" to be offered to ministry and Cairo University personnel.
- 6) Establishment of mid-career educational programs for ministry personnel.
- 7) Establishment of mid-career educational programs for Cairo University faculty members.
- 8) Provide laboratory equipment to Cairo University's departments.

FRED MOAVENZADEH

Upward Bound Program

The MIT-Wellesley Upward Bound program is a coeducational, multiracial, multiethnic educational program for Cambridge high-school aged youth. Now in its thirteenth year, the program services 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 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 in the area of goal setting or level of aspiration in the 1930s and '40s by the social psychologist Kurt Lewin and his associates. The program has met with good success, operating on the assumption that ego growth and academic performance are closely related. A developing ego needs to experience success in a warm and personal but structured environment to develop strongly, in both a personal and social sense. This development can be brought about through intervention outside of the family and 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. The program staff are often the first to see real academic promise in the youngsters. They also, together with teachers and fellow students, play a crucial role because what students think they can do is dependent on what others think they can do. The students' perceptions of their abilities, and therefore what they will try to accomplish, are thus to a large extent determined by the staff.

SUMMER PROGRAM

The Summer Program, conducted in residence on the Wellesley College campus for six weeks, is designed to provide the student with an intense academic and social experience. Classes are team-taught by experienced high school teachers, students from Wellesley College and MIT, and Upward Bound alumni now attending college. Upward Bound students carry three classes, each of which meets for 50 minutes, five days per week during the six-week summer program. Classes are small and conducted in a seminar fashion. Each student is required to take one mathematics and one humanities or social science course and one elective. Humanities and social science offerings include English, film studies, religion and world views, US history, social psychology, and cultural identity in America. Science courses include biology, physics, human physiology, computers, and chemistry, and are supported in part by a grant from IBM. 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; and a pre-calculus course for students who will be attending college in the fall.

THE ACADEMIC YEAR

The academic year program, while ostensibly less intense and dramatic, is equally important to that of the summer. Building on the motivation and enthusiasm developed over the summer, the academic year program is designed to help the student cope with the myriad academic, social, and family problems that confront him or her in Cambridge. To achieve this, the following programs, staffed primarily by MIT and Wellesley College undergraduates, have been developed and implemented.

Study Skills

The MIT Upward Bound offices are open for study five afternoons a week from 3:00 to 7:00 p.m. and one evening per week from 7:00 to 9:00 p.m. The office is also open for studying on Saturdays and Sundays from 10:00 a.m. to 1:00 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 MIT or Wellesley College undergraduates who meet regularly on a mutually convenient basis with the Upward Bound student and then report back to project staff. For 1980-81, space for meetings and tutoring will be available in the Cambridge Public High School during the day.

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 once a month for six hours. The Saturday program includes arts and crafts, drama, the use of the pool and gym, as well as other extracurricular activities.

Cambridge Community Support

The program staff supports students through professional consultation with public school administrators and teachers. Support also comes for the Cambridge community during periods of social stress due to the program's historical success in racial/ethnic interpersonal relationships. Staff members were asked by public school officials to assist in human relations workshops and dialogue after the tragic stabbing of a high school student this year.

College Report, Class of 1980

Twenty-two graduating seniors have been placed in colleges as follows: Alabama State University, Antioch College, Boston College, Dartmouth College, Franklin Pierce College, Georgia College, Howard University, Iowa State University, Macalester College, Morehouse College, New England College, Northeastern University, Salem State College, Spelman College, Springfield College, Southeastern Massachusetts University, University of Rochester, University of Vermont, and Wentworth Institute.

MARSHALL MILNER

Wellesley-MIT Exchange Program

In this, the twelfth year of our Exchange Program with Wellesley College, student cross-registration continued at substantially the same level it has maintained since the Program's inception. Wellesley enrollments in MIT subjects numbered 213 in the fall 1979 semester and 293 during the spring of 1980, while MIT students took 148 Wellesley courses in the fall and 184 courses in the spring. One of the interesting signs of the strength of the Exchange has been the diversity of the subjects and courses selected by the students. This diversity was again present in 1979-80. For example, the 293 spring enrollments at MIT by Wellesley students were in 139 distinct MIT subjects, scattered over the five Schools.

The past six years have seen a steady growth in faculty interactions between the two institutions. None of these has become substantial in size, but the number of small cooperative programs, jointly taught courses, and courses taught on the opposite campus has increased, and regular communication between faculties in related fields is more common now than ever before. Staff cooperation has also been on the increase. There are, for example, regular meetings between the staffs of the offices of student affairs.

During the year, the feeling grew that enough has changed so that it might be time for a review of the whole Exchange Program. There is good reason to think that such a review will be undertaken in the 1980-81 academic year and used as a basis for further strengthening the Exchange.

KENNETH M. HOFFMAN

School of Architecture and Planning

The continued excellence of the MIT School of Architecture and Planning will depend upon the School's successful response to society's needs. For our professions, these needs are exacerbated by diminishing natural resources, growing controversy around environmental protection, and deteriorating urban infrastructure. This past academic year, the School's response has been particularly notable in the substantial growth of its research, both in quality and volume. The School's research, managed mainly through the Laboratory of Architecture and Planning (LAP), has become a vital, cross-departmental part of the School's activities, as well as a reflection of its ties to practice and the outside world. A decade ago, the issue of field-based learning focused the School's educational concerns and was the theme of a Visiting Committee meeting. An upcoming meeting of this committee will similarly examine the School's research growth as it relates to both supporting and leading education in the School.

The Department of Architecture has inaugurated a new degree program -- S.M. in Architecture Studies -- which focuses on combining the study and practice of shaping the built environment with research on the nature of that built environment, on the forces which mold it, and on the design process itself. Another recent degree program -- S.M. in Visual Studies -- initially coalesced around growing and overlapping research of the relatively scattered components within visual studies. Establishing these efforts as a coherent professional field manifests another trend of growing importance -- a systematic strengthening of the collaboration of the media arts and technology within and outside the Institute.

The Department of Urban Studies and Planning has been at the same time reinforcing its efforts to improve the art and science of urban planning by dealing with issues like distribution of wealth, the peaceful resolution of conflict, and the re-establishment of the sense of community in urban areas. This has necessitated closer ties with MIT's social science departments as well as certain curricular modifications. At the undergraduate level, there has been a shift to problem solving in the public sector; at the master's level, practice-related skills have been given primary emphasis for planning practitioners. Combined with increased collaboration with other departments, these changes have given a sharper focus to the Department around environmental and public management issues.

The Visiting Committee

The Visiting Committee spent two days at the School in March 1979 inquiring into the programs of both Departments and into the potential sources of dissatisfaction among the students.

The 17 members (out of 22) found that the School had acted on the Committee's recommendations from the previous year and established the Master of Science in Architecture Studies program, and that the Department of Urban Studies had intensified its contacts with other schools, departments, and programs.

The Committee encouraged the School to seek endowment funds for a chair in building technology and recommended additional funds for research, the Community Fellows Program (CFP), the Special Program for Urban and Regional Studies (SPURS), as well as for foreign students.

The Committee members saw improvement in upper level design studios, especially in the third level environmental design studio, which they characterized as lively.

Finally, and not for the first time, the Committee expressed concern for what they called "shockingly inadequate" facilities in the School of Architecture and Planning.

The Aga Khan Program for Islamic Architecture

The Aga Khan Program for Islamic Architecture, administered jointly by Harvard and MIT and funded by generous gifts by His Highness the Aga Khan, was established in 1979. It is an educational and research program designed to provide architecture students with opportunities to study Islamic history and culture; to present scholars with the questions and problems faced by practitioners of architecture and planning; to make it possible for practicing professionals to learn about Islamic architecture and about contemporary issues; to gather and disseminate written and visual information about Islamic architecture in particular and the Muslim world in general, and to make it possible for practitioners to build new environments that reflect a sense of Islamic history and culture.

One aim of the Program is to increase the number of scholars trained to deal with the history and significance of Islam's architectural past as well as its contemporary architectural expressions and aspirations. A second aim is to create a resource center for the development, gathering, and dissemination of information for use by planners, government officials, teachers, and architects.

Two documentation centers have been established, one at Harvard, one at MIT with somewhat different orientations. At MIT, the focus is on contemporary Islamic architecture and urbanism; at Harvard, it is on Islamic architecture and art before 1900.

In the summer of 1980 the Program will offer, under the aegis of the LAP's Continuing Education series, a seminar entitled "Designing in Islamic Cultures." Results of this course will shape our consideration of managing similar programs in other countries.

The Aga Khan Program's Faculty Council at MIT consists of Dean William L. Porter and Professor Henry Millon of the Department of Architecture. The Advisory Committee members are Dean Porter and Professor Nazli Choucri of the Department of Political Science. Members of the Library Committee are Jay Lucker, Director of Libraries and Margaret DePopolo, Rotch Librarian. Permanent staff members for the Program are Margaret B. Sevchenko, Coordinator and Editor of publications (Harvard and MIT), and Richard Dewey, Bibliographer for the Aga Khan Documentation Center.

The Arts and Media Technology Facility

Planning and funding are well under way for the new Arts and Media Technology Facility that is to be located on the East Campus. The new center, designed by I. M. Pei and Partners, will provide space for the Architecture Machine, Electronic Music Section, Film/Video, Photography, Visual Language Workshop, related research projects, galleries, and an experimental media theater. Locating arts, media, and technology together in the new center will facilitate joint experimentation and other forms of collaboration. Construction is expected to start in 1981.

School Publication: *PLAN*

The School's publication *PLAN* has gone through a number of metamorphoses during its relatively short history of six years (it started as the Newsletter). A forthcoming special issue of *PLAN* will review the past decade of the School through interviews with selected faculty members and alumni.

We are currently planning a quarterly design journal to be sponsored jointly by the Berkeley College of Environmental Design and the MIT School of Architecture and Planning.

The Architecture Education Study

The two volumes of the Architecture Education Study, which was funded by the Andrew W. Mellon Foundation and directed by Dean Porter of MIT and Maurice Kilbridge of Harvard Graduate School of Design, are expected to come out before the end of 1980. One volume will include two case studies on studio teaching in two schools of architecture. A companion volume will contain interpretive essays based on the case studies.

The goal of the study, spelled out six years ago, was to "improve architecture education in the United States to meet the needs of our changing society." The starting point was a collective recognition by a consortium of the deans of eight eastern schools of architecture that "architectural education is an underdeveloped area of the academic world."

Four major issues which emerged from the study have been selected as themes for a concluding symposium in 1981. The symposium will be structured by the presentation of four papers, prepared by distinguished architecture educators, which reflect on the implications of the study for a larger audience. These papers, with comments and conclusions of symposium participants, and selected material from the original study, will constitute the final report of the Board of Directors to the Mellon Foundation.

Placement

Steps have been taken to help graduating architecture and planning students find suitable jobs once they leave the School. Jane Wells, assistant director of MIT's Career Planning and Placement Office, assists the School's students through workshops to prepare resumes and portfolios. She also provides leads and contacts with potential employers as well as lists of companies that students could approach on their own. Within the School, in the Department of Urban Studies, Susan Resteghini has been hired as a placement officer. These two officers pool their resources and share their information for the benefit of the students.

Degree Programs and Admissions

In the academic year 1979-80, there were 968 applications for September 1980 admission to the graduate programs in the School (an increase of 92 over the previous year). In the Department of Architecture, the M.Arch. program received 310 applications, of which 47 were offered admission and 29 have accepted. There were also 21 applications for continuing graduate study from the Department's undergraduate programs, with 16 being offered admission and 15 accepting. In the other graduate programs, admissions have gone as follows: the S.M.Arch.S. program received 132 applications, of which 48 were offered admission and 38 accepted; the S.M.Vis.S. program had 58 applicants, offered admission to 19 and has 18 acceptances; 28 applied to the Ph.D. program, 6 were offered admission and 5 have accepted.

The M.C.P. program in the Department of Urban Studies and Planning (DUSP) received 334 applications, of which 64 were offered admission. A total of 85 students applied to the Ph.D. program, with 27 being offered admission. In the Department's special non-degree programs, SPURS (Special Program for Urban and Regional Studies of Developing Countries) and the Community Fellows Program (CFP), 37 people have been invited to participate in 1980-81: 27 for SPURS (out of 62 applications) and 10 for the CFP (from 23 applications). So far, SPURS has 17 acceptances and the CFP, 7.

Degrees awarded to the School's students in September 1979, February 1980, and June 1980 totaled 105. In Architecture, 64 degrees were awarded: 26 B.S.A.D., 18 M.Arch., 16 M.Arch.A.S., 1 S.M.Arch.S., and 3 S.M.Vis.S. The 41 degrees awarded in DUSP were distributed as follows: 10 S.B., 26 M.C.P., and 5 Ph.D.

The Dean's Office

Lois Craig, special associate to the Dean, was promoted in May to Associate Dean. Ms. Craig joined the School's Laboratory of Architecture and Planning as a research affiliate in 1979 after a five-year assignment for the National Endowment for the Arts. She assumed the responsibilities of Special Associate to the Dean in August 1979, when former Associate Dean Florence Ladd accepted a position as Dean of Students at Wellesley College.

Dean Porter's resignation, announced one year ago, will be effective December 31, 1980. He plans to be on sabbatical in 1981 and then return to the faculty of the School.

School of Architecture and Planning

During the past year, a committee of the School has conducted a search for a new dean. The committee members are: Larry Bacow, Assistant Professor of Law and Environmental Policy, DUSP; Muriel Cooper, Associate Professor of Visual Studies and Director of the Visible Language Workshop, Architecture; Langley Keyes, Professor of City and Regional Planning, DUSP (co-chairman); John Myer, Professor of Architecture, Architecture (co-chairman); Kim Flippen, M.C.P. candidate, DUSP; and Donna Duerk, M. Arch.A.S. candidate, Architecture. The administration is currently reviewing the committee's report.

WILLIAM L. PORTER

STUDENT ENROLLMENT AND COMPOSITION 1979-80 ⁺

	<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>							
Undergraduate	90	24	27%	5	6%	7	8%
M.Arch.	95	39	41%	8	8%	5	5%
M.Arch.A.S./S.M.Arch.S.	44	14	32%	2	5%	38	86%
S.M.Vis.S.	20	6	30%	1	5%	2	10%
Ph.D.	15	7	47%	0	0%	5	33%
Special Students**							
Undergraduate	0	0	0%	0	0%	0	0%
Graduate	10	6	60%	0	0%	2	20%
Joint M.Arch/M.C.P.	5	1	20%	1	20%	2	40%
<u>Architecture Totals</u>	279	97	35%	17	6%	61	22%
<u>Department of Urban Studies and Planning</u>							
Undergraduate	30	12	40%	1	3%	2	7%
M.C.P.	76	34	45%	32	42%	6	8%
Ph.D.	84	35	42%	10	12%	25	30%
Special Students**							
SPURS***	16	5	31%	0	0%	16	100%
C.F.P.***	8	4	50%	8	100%	0	0%
Other	10	7	70%	0	0%	0	0%
Joint M.Arch/M.C.P.	8	2	25%	0	0%	1	13%
Joint Civil/DUSP	0	0	0%	0	0%	0	0%
<u>DUSP Totals</u>	232	99	43%	51	22%	50	22%
<u>School</u>							
Undergraduates	120	36	30%	6	5%	9	8%
Graduates	347	138	40%	54	16%	84	24%
Special Students**	44	22	50%	8	18%	18	41%
TOTAL ENROLLMENT	511	196	38%	68	13%	111	22%

+ Enrollment figures are a five-week count of students registered in the fall.

** 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 (CFP), established in 1971.

FACULTY, OTHER ACADEMIC STAFF, AND RESEARCH STAFF -- 1977-78, 1978-79, 1979-80

	1977-78			1978-79			1979-80		
	Total	E.F.T.	Women Minority	Total	E.F.T.	Women Minority	Total	E.F.T.	Women Minority
<u>Architecture</u>									
Faculty	38	29	7	45	38	6	35	31.5	6
Other Academic Staff	25	14	7	23	16.5	7	33	17.5	10
Research Staff	6	5	-	7	6.5	-	7	6	-
Without Pay	-	-	-	-	-	-	-	-	-
<u>DUSP</u>									
Faculty	31	27.25	5	29	26.83	3	27	24.6	3
Other Academic Staff	7	2.25	-	7	4.33	-	19	10.38	7
Research Staff	2	2	2	3	3	2	3	1.7	2
Without Pay	-	-	-	2	-	-	9	-	3
<u>Laboratory of Architecture and Planning</u>									
Faculty	-	-	-	-	-	-	-	-	-
Other Academic Staff	2	2	-	2	2	-	2	2	-
Research Staff	3	3	1	4	3.5	1	4	4.51	3
Without Pay	2	-	-	6	3	2	9	-	3
<u>SCHOOL TOTALS</u>									
Faculty	69	56.25	12	74	64.83	9	62	56.1	9
Other Academic Staff	34	18.25	7	32	22.83	7	54	29.88	17
Research Staff	11	10	3	14	13	3	14	12.21	5
Without Pay	2	-	-	8	3	2	18	-	6

Department of Architecture

The Department continued its efforts to develop its programmatic structure within a broader, long-term strategy to continue its leadership role in architectural education. This year saw the implementation of the conjunction of three Master's programs: Master of Architecture (M.Arch.), Master of Science in Architecture Studies (S.M.Arch.S.), and Master of Science in Visual Studies (S.M.Vis.S.). With the Ph.D. program, this established a framework for artistic and intellectual exploration that will allow us to anticipate and influence the fundamental changes expected in the professional field for the coming decade.

The recent establishment of the Aga Khan Program for Islamic Architecture and the current plans for a new facility in Arts and Media Technology are new important developments within this broader framework.

DEGREE PROGRAMS

M.Arch.

The M.Arch. Committee was chaired this year by Professor Imre Halasz. Professors Maurice Smith and Chester Sprague led the Department admissions committee for the program. After reviewing 310 applications, places were offered to 29 students for fall 1980. Within the program, efforts continue to clarify the distinction between levels of design studio, to integrate teaching efforts within each level, to coordinate student guidance and evaluation, and to coordinate studio subject matter with other subject work in the Department.

A standing search committee, chaired by Professor John Myer, has worked during the year to bring a number of visiting teachers from practice and abroad. Four visiting appointments were made to the design staff in the 1979-80 academic year, and more are scheduled for coming terms.

In fall 1979, seven students (5 M.Arch. and 2 S.M.Arch.S.) studied in Urbino, Italy at the International Laboratory for Architecture and Urban Design (ILAUD). Professor Sprague was faculty representative to ILAUD. The group attempted to develop greater continuity between ILAUD and MIT studies this year, presenting a report on tractable architecture, followed in the spring term at MIT by a more specific study of housing types. It is intended that developments from these studies be the subject of research done by our students in Urbino in the next academic year.

The Independent Activities Period (IAP) this January featured a highly successful studio for M.Arch. students directed by an old friend of the Department, Dutch architect Herman Hertzberger. Twenty students spent a lively and productive two weeks under Hertzberger's direction designing a music school on a seacoast site. W. Brown Morton, Chief of the Technical Preservation Services, US Department of Interior, and a leading conservation consultant, offered a two-week subject during IAP titled "Problems in the Conservation of Architecture and Landscape." This activity offered students the opportunity to examine the variety of rules for architects in conservation, including technical analysis of building conditions, physical interventions for preservation, and preservation planning.

Professor Edward Allen and Research Associate Timothy Johnson continued teaching building technology for a second year in studio format -- Professor Allen in Buildings 5 and 10 and Mr. Johnson in the Solar House.

Awards made to graduating M.Arch. students in the 1979-80 academic year were as follows: Renee Chow received the American Institute of Architects (AIA) Medal and Steven Imrich the

AIA Certificate. The Chandler Prize was given to Lawrence Chang and the Chamberlain Prize to Alan Joslin. The Alpha Rho Chi Medal was won by John Graham, Paul Fallon received the Tucker-Voss Award, and Hinckley Traveling Fellowships were awarded to Michael Raphael and Kenneth Wong.

S.M.Arch.S.

The first class of 22 students entered the S.M.Arch.S. program in fall 1979 to specialize in Environmental Design, Housing and Settlement Design, or Building Systems Design. The program continues to attract a large number of highly qualified applicants from all parts of the world. Professor Julian Beinart chairs this program, which has accepted 37 students for fall 1980.

Two core subjects in methods of inquiry and economics of the built environment were taught for the first time this year. Professor Karen Polenske was available to teach Economic Analysis. The second core subject, Methods of Inquiry in Architecture Studies, was developed and taught by Professors Beinart, Sandra Howell, and Michael Gerszo.

New faculty positions were established in Anthropology in Architecture, Architectural Illumination, and Environmental Control in Buildings.

A faculty committee, chaired and coordinated by Professor Allen, worked through the year on re-examination of the building technology curriculum and research agenda.

S.M.Vis.S.

Eleven graduate students entered the S.M.Vis.S. program in fall 1979 to study in the Center for Advanced Visual Studies, the Visible Language Workshop (VLW), Film/Video, Photography, and the Architecture Machine Group. A joint committee from the five sections, chaired by Professor Nicholas Negroponte, has admitted 14 students for 1980-81. Applications from excellent candidates have shown a marked increase as the expanded program continues to develop.

The S.M.Vis.S. program benefited greatly from development money this year, allowing seed money to be allocated for graduate student research, and development of new subjects in several of the sections. "Aspects of Digital Video," in the Architecture Machine Group, and two new graduate seminars in photography, were taught for the first time. "Edges of Education, Research and Art," taught by Professor Muriel Cooper in the VLW, enrolled graduate students from all sections of the program.

In April 1980 Robert Frank was at MIT as a visiting professor in the Creative Photography Laboratory. Professor Frank, author of a definitive work on 35mm photography entitled *The Americans*, spent the month working with students in both Photography and Film/Video.

A number of grants were received for projects within the S.M.Vis.S. program from the Council for the Arts at MIT. Among these were an award to Professor Cooper for the purchase of equipment for small book production, and an award to two graduate students to initiate a national distribution network for award-winning films and video produced by MIT students in the Film/Video section. Support for one year's publication of a magazine to be produced by graduate students in the Photography section was granted by the Arts Council, with support for a second year pledged by the Polaroid Corporation. Two grants were made to members of the Center for Advanced Visual Studies, Aldo Tambellini and Bernd Kracke, for the staging of special media events at MIT.

Thirteen films by graduate students, graduates, staff, and faculty of the Department's Film/Video section were shown at the first Boston Independent Film Festival in April 1980. Films by MIT students and staff also have been screened by this year's Berlin Film Festival for Young Filmmakers, the American Film Festival, the Athens International Film Festival, the Museum of Modern Art, and the Whitney Museum's New American Filmmakers series.

Department of Architecture

The Photo Gallery in the Creative Photography Lab, which serves as both a public and a teaching gallery, scheduled a series of six exhibitions this year covering many aspects of photography. Among these were "Fantastic Photography," organized by the Canon Photo Gallery, Amsterdam, Holland; an exhibition of student work; and a show open to the public for submission. For this show, 300 portfolios were received, from which the works of 55 photographers from all over the country were selected to be exhibited.

The design of a new Arts and Media Technology facility has been undertaken by I. M. Pei and Partners. Programming for the building has included the faculty of the S.M.Vis.S. program, along with representatives from the Electronic Music Laboratory, the Exhibitions Program, and Educational Video Resources. The design of this building has at once been the design of a new intellectual pursuit, deeply rooted in new means of and technologies for communications and the arts, which has initiated new collaborations and research programs.

William Parker, a student in the S.M.Vis.S. program, received the Institute's Laya and Jerome B. Wiesner Award for distinguished accomplishment in the creative arts.

Ph.D.

The Ph.D. program had four students enter in fall 1979, including the first Aga Khan Fellow. The Ph.D. Committee, chaired by Professor Stanford Anderson, has admitted five new graduate students for fall 1980, all specializing in the history of architecture. The decision to concentrate on architectural history to build the Ph.D. program results in part from the new possibilities offered by the Aga Khan endowment. In the 1980-81 academic year, the Department will have the first Aga Khan Visiting Professors of Islamic Architecture. In addition, a search will continue for a Professor of Islamic Architecture to teach in the Department and do research with historians and architects in the Islamic world and the West. A series of lectures by seven noted scholars of Islamic Architecture was also presented this year under the sponsorship of the same grant.

The Department received national recognition at the annual meeting of the Society of Architectural Historians in Madison, Wisconsin in April 1980. Professor Anderson was asked, as one of four panelists representing universities across the country, to present the MIT doctoral program to a special session on graduate education in the history of architecture.

Undergraduate

Though undergraduate enrollment in the Bachelor of Science in Architectural Design (B.S.A.D.) has declined, two introductory subjects in architecture have attracted large numbers of undergraduates to the Department. These are: Built Form Observation (4.26) taught by Professor Barry Zevin and Issues in Architecture (4.01) taught by Professor Jan Wampler. Humanities Distribution Subjects in the history of art and architecture offered by the Department and taught by Professors David Friedman and Beeke Sell Tower continue to have large enrollments. And, as in past years, the Department's subject offerings in film/video, photography, computer graphics, and building technology continued to attract undergraduate students from throughout the Institute, as well as from Wellesley and Harvard colleges.

The Department's Internship Program, in its second year, placed 20 M.Arch. students in architectural offices in New York and Boston during IAP. The Department is grateful for the organization and leadership in this effort by Professor Allen, chairman of the B.S.A.D. program.

FACULTY

Professor Leon Groisser was Acting Head of the Department in the fall term, while Professor John Habraken was on leave.

The Department was pleased to have Giancarlo De Carlo return as Adjunct Professor of Architecture. William Lam was appointed Adjunct Professor of Building Technology and will teach

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and direct research in architectural illumination. Edward Robbins was appointed Assistant Professor in Anthropology in Architecture and Harvey Bryan was appointed Assistant Professor in Building Technology to teach environmental control in buildings.

Professor Sell Tower, formerly at Connecticut College, was appointed Assistant Professor of the History of Art. Robert Rettig was a Lecturer in the Department for the year, teaching a subject on urban development, architecture, and preservation in Boston and Cambridge.

Professor Dogan Kuban of Istanbul Technical University was appointed to the faculty this year as Aga Khan Visiting Professor of Islamic Architecture and Urbanism.

Michael Pittas, Director of the Design Arts Program at the National Endowment for the Arts, joined the Department in the fall as a Visiting Associate Professor to teach a subject on Urban Implementation Strategies. Kristina Hooper, from the University of California at Santa Cruz, was appointed Visiting Assistant Professor with the Architecture Machine Group.

A number of visiting architects were appointed as lecturers and instructors on the architectural design staff this year. Andrea Leers and Linda Tuttle taught with the Level I team in the fall term, Susie Kim led a Level II studio in fall 1979, and John Sharrat gave a Level III studio in the spring term.

Professor Henry Millon, who has been named Professor-in-Charge of the Center for Advanced Study at the National Gallery in Washington, DC, will continue his association with the Department under a new appointment as a visiting professor.

Nicholas Negroponte, who heads the Architecture Machine group, was promoted to the rank of full professor.

Paul Earls served as Director of the Center for Advanced Visual Studies in fall 1979, in the absence of Professor Otto Piene who was on leave. Professor Robert Slattery was on leave this year; Professors Myer and Wampler were on leave in the spring term.

Professor Eric Dluhosch and Professors Habraken and Anderson were participants this spring in the International Symposium on Islamic Architecture and Urbanism, at King Faisal University, Dammam, Saudi Arabia.

Professor Howell was the invited keynote speaker at the Second Annual Nova Behavioral Conference at Nova University in March 1980.

Professor Anne Vernez-Moudon was chairwoman and delivered the keynote presentation at this year's conference of the Environmental Design Research Agency in Charleston, South Carolina.

Professors Allen and Douglas Mahone won the US Department of Housing and Urban Development Cycle-5 Passive Solar Demonstration Award, for their design of a house built in Wichita, Kansas. They were also recipients of the New England Regional Governors' Conference Solar Design Award for a house in Mattapoisett, Massachusetts.

Professor Habraken received the biannual Dutch National "David Roëll" award for Achievement in the Arts.

RESEARCH

The volume of research increased in the Department this year, involving more faculty, students, and staff. The Architecture Machine Group has reached a \$1 million per year scale of research. Work continues on the laboratory's three major programs: spatial data management, mapping by yourself, and personalized movies.

Professor Howell began work this year on a three-year project, determinants of housing choice among the elderly, funded by the Department of Health, Education and Welfare Agency on Aging.

As principal investigator for this project, Professor Howell will coordinate the work of seven scholars in behavioral science at universities in the US and Canada.

Professors Sprague and Antonio DiMambro worked on an investigation of tractability in housing in neighborhood form.

Professor Allen, with Professor Mahone, is conducting research for the US Department of Energy, through the University of Pennsylvania, to develop teaching materials for architectural schools in passive energy design.

Principal Research Associate Johnson continued his Solar V research, funded by the Department of Energy, on passive solar energy and utilization of building materials.

Compupaint, Inc. has extended and increased its support for development of computer systems for the production of large-scale imagery in color. The research is directed by Professor Ron MacNeil in the Visible Language Workshop.

Professors Dluhosch, Waclaw Zalewski, and Albert Dietz and Research Associate Reinhardt Goethert continued joint research with Cairo University on the housing and construction industry of Egypt, as part of the MIT-Cairo University Technology Adaptation Program (TAP). Professor Habraken was principal investigator.

Work on design methods for urban tissue design was continued this year as the second of a three-year grant by the Ernest Grunsfeld Memorial Fund, matched by MIT. Ten students participated under the coordination of Professor Habraken.

Professor Mahone and Timothy Johnson are now working with the Energy Lab at MIT to develop a long-term program of research about buildings and insulation. In addition, Professor Mahone is working to develop materials for case method teaching about energy design. This is being funded by the National Endowment for the Arts.

Professor Vernez-Moudon participated this year in a research project to review urban environmental design administration in several American cities. The project was funded by the Department of Housing and Urban Design, and was done in collaboration with Rice University and the University of California at Berkeley. Professor Gary Hack of the Department of Urban Studies and Planning was principal investigator.

OTHER EVENTS

A number of visiting scholars were appointed in 1979-80 to work with Department faculty in their areas of interest. Architect and structural engineer Daniel Gat spent part of his sabbatical leave from Technion University in Haifa, Israel, as a visiting scholar working among the faculty in the building technology group. Hasso Schreck, from Technische Universität, Berlin, returned this year in the spring term to participate in both the housing and building technology group teaching and research. Konrad Weller, also from Technische Universität, was a visiting scholar in the winter term. Rafaat El-Zoghby, architect and professor from Ain Shams University, Cairo, worked for one year with the Department's housing group; Washington A. Mendez from Universidad de los Andes, Merida, Venezuela, was a visiting scholar for one year working on building technology for prefabricated building systems. Finally, Franz Ziegler from International Land Use Consulting (ILACO) in The Netherlands came in the spring term as a visiting engineer.

During IAP 1980, the School of Architecture and Planning sponsored the annual conference of the International Laboratory for Architecture and Urban Design. Entitled "Participation and the Building Community," the conference was attended by about 80 scholars and researchers from European, Canadian, and American universities. Many community leaders and organizers, professionals and students from the Boston area also participated in the seminars, lectures, and field trips. The objective of the conference was to understand better the interrelationship between architecture and citizen participation in the planning design processes. Two significant

participatory processes in Boston were presented and discussed; the experience of the residents of low-income Hispanic neighborhood (IBA) in the South End of Boston, and the Southwest Corridor Project (SWCP). Proceedings of the conference and summaries of seminar discussions are to be published in the fall of 1980.

In October 1979 the Department received a grant from the National Endowment for the Arts to be used as incentive awards to design students doing thesis work at the Master's level. The intention of the awards was to cover expenses necessary to make a thesis of higher quality in substance and/or production, and they were given on the merit of a thesis proposal rather than on the basis of financial need. Eight M.Arch. and eight S.M.Arch.S. students received funds from this grant.

The Visible Language Workshop presented a three-part workshop on Graphic Design: Computers and Other Tools during summer session 1979. The workshop attracted 30 educators, designers, and people from industry.

The Department hosted for the second time the Energy Design Institute of the Association of Collegiate Schools of Architecture. Professors Mahone, Allen and Mr. Johnson lectured in the seminar.

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N. JOHN HABRAKEN

Department of Urban Studies and Planning

In the 1980s and beyond, MIT's mission must change to reflect the shifting pressures on American society as well as the needs of other countries. While new discoveries in science and engineering will continue to be important to the further growth and development of the industrial sectors of the world's economy, the stability of our society and the enhancement of the quality of everyday life will depend upon our ability to come to grips with the issues of the distribution of wealth, environmental protection, the peaceful resolution of conflict, and the re-establishment of a sense of community. In the decades ahead, MIT's contributions to the resolution of these terribly difficult problems will depend heavily upon the capabilities of the Institute's departments and centers involved with the generation and application of social scientific knowledge and techniques. The Department of Urban Studies and Planning (DUSP) is in the process of preparing for this transition -- building closer ties to the basic social science departments at the Institute, designing curricula that emphasize the application of social science knowledge and technique to the resolution of critical societal problems, and initiating research activities that will help to build theory that can usefully inform public policy and governmental action.

During the past academic year, DUSP faculty, students, and alumni have engaged in a series of teaching, research, and field-linked activities that reflect the traditional strengths of the Department but also point a direction for the future. At the undergraduate level, the Department is moving toward a redefinition of its teaching role in the Institute -- away from a descriptive focus on the problems of cities and towards an emphasis on problem solving in the public sector. At the master's level, the Department has instituted a new specialization in Public Policy and Management and re-emphasized the need for all professional degree candidates to acquire a common set of practice-related skills. At the doctoral level, we have implemented a new Instructor's Program designed to enhance the teaching competence of Ph.D. candidates pursuing teaching careers. We also have initiated a new Postdoctoral Fellows Program aimed at deepening our research activities.

Several difficult questions, central to the organization and mission of our Department, have preoccupied us this past year: 1) How can we help our students understand and become part of a profession that has a rather limited view of what its practitioners need to know while at the same time opening our students' eyes to the broader range of knowledge and skills needed by those who would intervene effectively in the public sector? 2) How can we balance classroom learning that emphasizes the systematic study of science and social science with the rough-and-tumble, learning-by-doing that characterizes most internship or field-linked learning? 3) How can we introduce our students to the heavily value-laden consideration of topics such as redistributive justice, institutional racism, and the nature of the good society without appearing,

on the one hand, to be legislating appropriate values or, on the other hand, to be denying our own ideological commitments as individual faculty members? 4) How can we prepare our students to be effective in the professional roles that they are likely to fill in the next few years while at the same time encouraging them to be critical of current institutional arrangements that create and sustain severe disadvantages for large segments of society? We have not reached agreement on how best to handle these questions, but just the effort to ask them has moved us closer to a satisfactory response.

The Department is still anchored to its concern for "the quality of life in places and spaces," but the entire faculty is equally committed to the belief that improvements in the quality of life can come only through carefully planned institutional interventions that occur well beyond the level of a single neighborhood or community, and typically require concerted political action and the application of knowledge and skills borrowed from a variety of disciplines and fields.

As we approach a clear understanding of the knowledge and skills that planning practitioners need to be effective, it is increasingly difficult to accept the boundaries that were once appropriate to our field. While it might appear that the Department's efforts to borrow from other fields and disciplines reflect a lack of focus or a failure to define a clear mission, the opposite is true. The Department of Urban Studies and Planning is shaping a new role for itself within the Institute (as are other City and Regional Planning departments at other universities) and a new sense of identity as a department emphasizing problem solving in the public sector. This emerging configuration stresses our professional orientation (i.e., we are not another social science department) as well as our intention to prepare practitioners, analysts, and activists with the essential skills and commitments needed to come to grips with the problem of improving the quality of life in urban areas.

PROGRAM DEVELOPMENTS

The Undergraduate Program

Professor Aaron Fleisher (director) and Professor Lawrence Bacow (associate director) continued work on the preparation of a "white paper" defining a new orientation for the S.B. in Urban Studies. An S.B. option, implemented this past year and focusing on the special problems of developing nations, did not attract many concentrators or majors. Continued efforts will be made to find ways of providing engineering majors with international interests an opportunity to double major or concentrate in Course XI. The joint Public Policy program with Political Science continued to flourish. Relationships between the two Departments are excellent and enrollment in jointly listed public policy subjects is at an all-time high. The joint degree program (with Course I) in Environmental Planning was hurt somewhat by the absence of Professor Gakenheimer, who was on leave for the year. Special efforts will be made in the coming year to alert undergraduates with an interest in environmental policy and planning to the availability of this joint degree option.

The Professional Degree Program

Professor Langley Keyes (director) and the members of the Master of City Planning (M.C.P.) Committee spent a substantial amount of time searching for ways of strengthening the professional focus in the Master's Program. The creation of a new specialization in Public Policy and Management (in response to student demand) was made somewhat easier by the receipt of the Department of Health, Education and Welfare's Public Policy Intern Program award. This internship program, headed by Professor Joseph Ferreira, provided fellowship support for 10 M.C.P. candidates and enabled them to secure internships with public agencies or with faculty members working with public agencies on a range of public policy questions (environmental regulation, the impact of energy prices on the housing market, and discrimination in the insurance industry). The US Department of Housing and Urban Development (HUD) provided support once again this year for 15 minority student interns in the DUSP. Incoming minority students were placed in neighborhood, municipal, and state agencies involved in

various aspects of community development. HUD interns, under the supervision of Professor Tunney Lee, also took part in a weekly seminar designed to help students link their internship assignments to their classroom work. The HUD Intern Program won the Institute's Sizer Award this year for "the campus activity that made the greatest contribution to student life."

The various activity area groups in the Department initiated a range of activities. The Neighborhood and Community Development Group, headed by Professor Lee, continued their neighborhood colloquium -- bringing speakers from city government and various Boston neighborhoods to interact with students and faculty at MIT. The Developing Countries Group, headed by Professor Lloyd Rodwin, jointly hosted a great many speakers with the SPURS Program (see below). The Environmental Policy Group, under the leadership of Professor Bacow, initiated several new research projects focusing on environmental mediation and environmental regulatory reform. The Environmental Design Group, headed by Professor Gary Hack, pursued its usual active program of speakers, workshops, its annual Spring Think (aimed at evaluating the strengths and weaknesses of the environmental design curriculum), and began work on the preparation of a white paper analyzing long-term options for the further development of the Environmental Design Program in the School. The Public Policy and Management Group, headed by Professor Hassan Minor, was probably the most active of all the activity area groups in the Department. David Mundell, Associate Director of the Congressional Budget Office, and Donna Shalala, Assistant Secretary of the US Department of Housing and Urban Development (in charge of urban policy research) headed the list of outstanding speakers. The public policy group also spent a great deal of time analyzing curriculum development needs in the public management field.

Two other items regarding the professional degree program are worthy of note. The Department's effort to implement a series of Methods Modules (six- to nine-week mini-courses aimed at teaching basic analytic techniques) is now complete. Ten modules were in place this year ranging from statistical analysis, to survey research, to decision analysis, to graphic and communication techniques. We will continue to refine these modules and add to the list as the need arises. Finally, the Department initiated a formal link to the MIT Writing Program this year. In an effort to improve the writing skills of professional degree candidates, the Department has arranged for a member of the Writing Program to work with students in the required Planning Process core course. This tie to the Writing Program will be expanded next year.

Ph.D. Program

The Doctoral Program Committee, under the leadership of Professor Robert Fogelson, continued its effort to tighten up the administration of the program. Students are now moving through the program in a more deliberate way and advisors are increasingly involved in supervising each student's progress on a semester-by-semester basis.

The Department also has initiated an Instructor's Program for advanced doctoral candidates. While Ph.D. candidates have always served as graduate instructors, we never before tried to bring instructors together on a regular basis to discuss the problems of teaching. We will continue this program and expand the range of issues that instructors review with outside guests, in an effort to support those students with an interest in teaching careers. Along these same lines we have begun to encourage advanced doctoral candidates with an interest in teaching to participate in the Institute's Undergraduate Seminar Program. The more teaching opportunities doctoral candidates have, while still working closely with their faculty advisors, the more likely they are to succeed in their first teaching assignments as full-fledged faculty members at other universities.

The initiation of Proseminars has augmented the course offerings available to advanced doctoral candidates. Faculty members are being encouraged to offer at least one Proseminar every other year highlighting research at the forefront of each of the areas of specialization in the Department. We expect these small research groups to provide continuing contact among advanced students, something that usually does not occur once students begin work on their examinations and dissertations.

SPURS

This year SPURS had 16 Fellows and four Associates, the highest number to date. There were four Fellows from Asia, one from Africa, three from Europe (including one from USSR) and eight from Latin America. In addition, there were four SPURS Associates: Gordon Stephenson (Great Britain), Nailton Santos (Brazil), Simon Fass (Canada), and Benjamin Reif (Venezuela).

Wednesday luncheons continued to serve as a meeting point for SPURS, DUSP students and faculty, and others in the Boston region and beyond, with an interest in developing countries. Speakers from overseas included Professor Ignacy Sachs, Director of the Ecole des Hautes Etudes en Science Sociales in Paris; Professor Ervin Galantay from the Ecole Polytechnique Federal de Lausanne, Switzerland; Shmuel Eisenstadt, Professor of Sociology at Hebrew University, Jerusalem; and Ivan Szelenyi, newly appointed Professor of Sociology, University of Wisconsin (formerly from Hungary). Speakers from the Boston area included Professor Raymond Vernon, former director of the Center for International Affairs, Harvard University and Professor Robert Solow, Institute Professor in Economics at MIT.

The Seminars in which Fellows present their past and current work received a boost this year with the introduction of wine and cheese. SPURS Fellows visited major international development and national planning agencies in New York and Washington, DC during the spring recess. The agencies visited in these cities included United Nations Development Program, US/AID, the World Bank, the Economic Development Administration, and the Senate Foreign Relations Committee Staff Office on Capitol Hill.

The SPURS Program was one of 10 chosen from 60 institutes invited to submit proposals for participation in the new Humphrey Fellows Program. In this first year, three Humphrey Fellows were placed in SPURS: Carlos Brando (Brazil), Selman Erguden (Turkey) and Zenaida Manalo (Philippines). For the 1980-81 academic year, five Humphrey Fellows have been accepted.

Community Fellows Program

National interest in the Community Fellows Program continued to increase. Applications were up once again. There were seven Fellows accepted this year: Raymond Almeida, Executive Director of the American Committee for Cape Verde; Edward Cooper, President of Highland Park 400, a senior citizens advocacy group; Agnes English, Co-Founder of the Marcus Garvey Youth Center in Boston; Dianna Johnson, a criminal justice planner for the city of Atlanta; Gerald Roybal, member of the Traditional Pit River Tribe in California; Domingo Garcia, Executive Director of the Ibero-American Action League; and Kenneth Garcia, Administrative Assistant to the Director of Community Development in Lincoln Heights, Ohio.

The Provost's Office appointed a committee, headed by Gregory Smith, a member of the MIT Corporation, to evaluate the Fellows Program. The Report of that committee should help to determine the future of the Fellows Program.

OTHER DEVELOPMENTS

The Department succeeded in initiating a number of new research projects this past year, including Professor Gakenheimer's Agency for International Development-sponsored research on urban transportation planning in Cairo; Professor Richard Larson's Law Enforcement & Assistance Administration-sponsored study of the methods in criminal justice evaluation; Professor Hack's HUD-sponsored analysis of urban and community impact statements; Professor Larry Susskind's German Marshall Fund-sponsored study of citizen participation in Western European cities; Mr. Fogelson's Twentieth Century Fund-sponsored study of public employee unions and their pension problems; and Professor Karen Polenske's NSF-funded work on the state-of-the-art in multiregional modeling. Other faculty members brought research projects in through the Laboratory of Architecture and Planning, the MIT-Harvard Joint Center for Urban Studies, and the MIT Energy Laboratory.

Many faculty members published books, monographs, and articles during the past academic year. The list would be far too long to include here. Three books deserve special note, however. Professor Arthur Solomon's *The Prospective City* (MIT Press), Professor Bacow's *Bargaining for Job Safety and Health* (MIT Press), and Professor Bennett Harrison's *Capital and Communities: The Causes and Consequences of Private Disinvestment* (The Progressive Alliance). Professor Solomon's edited volume provides an interesting and valuable agenda for urban policy research for the next decade. Professor Bacow's book is an important new volume in the field of environmental regulation. Professor Harrison's monograph represents a continuing commitment on the part of several faculty in our Department to look at policy-related questions relating to the future development of central cities in the United States and overseas.

The Department continued to expand its publication program. The *DUSP News*, published every other week, has become a popular vehicle for faculty and students anxious to put forward provisional thoughts about current issues. The Newsletter is circulated throughout MIT as well as to other planning schools. The alumni version of the *DUSP News* includes highlights excerpted from each semester's newsletters. Copies are sent twice a year to all alumni of the School of Architecture and Planning. The Department has joined the Laboratory of Architecture and Planning in sponsoring a working paper series. Student theses and research project reports can now be made available (and advertised) on an efficient basis. Finally, the Laboratory and the Department now provide an editorial home for *The Environmental Impact Assessment Review*, a quarterly publication covering the latest research and practice in the environmental planning field.

The number of "special" events in the Department is more than anyone could or should be expected to stay abreast of. There were, however, three "special" events that should be noted. During fall 1979, Professor Larson hosted a national conference on education on public policy and planning. More than 100 educators and policy analysts attended. Most MIT students and faculty attended at least some of the three days of seminars, workshops, lectures, and presentations. The conference represented a milestone in the development of public policy analysis as a focus in the planning field. During the January Independent Activities Period (IAP) students and faculty sponsored more than two dozen mini-courses, one-day presentations, and unusual events. Almost everyone in the Department participated in at least one of these activities. IAP continues to provide an extraordinary opportunity for the creative exploration of topics of interest to students and faculty. During the spring, the Department, the Joint Center for Urban Studies, and the Program in Science, Technology, and Society (STS) sponsored a seminar on the "Future of the New England Economy." Business labor leaders, and neighborhood activists met with students and faculty to explore the economic, political, social, and technological issues at stake in planning for the future of the region. This kind of interaction on topics of current concern to the Boston area provides an ideal model of the kinds of collaboration the DUSP expects to have in the future with the STS Program.

The number of students applying for admission to our professional degree program continues to grow (we now receive nine applicants for each place) while departments like ours at other universities have experienced a decline in applications. Applications to our Ph.D. program number approximately four applicants per place. Minority student enrollment continued to grow. Fifty percent of the students offered admission to our professional degree program for the coming year are American minorities. Fifty percent are women.

The final accomplishment I would like to note concerns the creation of our new Postdoctoral Fellows Program. Modeled after the Moore Instructorship Program in Mathematics, postdoctoral appointments in the DUSP allow recent Ph.D.s to spend a year studying, writing, and teaching at MIT. We have attempted to select postdoctoral fellows likely to secure teaching posts at other planning schools in the US and abroad. We will thus have an opportunity to export our view of planning education. At the same time, we are seeking postdoctoral fellows involved in the most interesting research projects at other sister departments. Their presence at MIT allows us to discover more about research going on elsewhere. The applications to the new Postdoctoral Fellows Program have been excellent. We hope to recruit two or three postdoctoral fellows every year.

Problems

The Department faces four nagging and persistent problems: insufficient student aid, lack of space for program activities and faculty offices, declining undergraduate enrollment, and a number of relatively weak ties to departments and centers to which we ought to be much closer.

The student aid problem grows worse each year. Tuition is rising, and outside sources of funding are falling. Research funds in our field are being cut back by foundations and federal agencies. The Department of Housing and Urban Development threatens every year to eliminate the HUD Intern Program. We have very limited income from School-wide and departmental endowments. Tuition increases have made it almost impossible for us to guarantee our students even half the funds they need to cover tuition and living costs at the Institute.

For the past several years the Department has been complaining about the lack of space and the debilitating configuration of the spaces we presently occupy. I'm not sure what good it does to repeat these complaints each year, but I feel obliged to mention the fact that the space problem has not diminished. Quite the contrary, it is more worrisome than ever.

Undergraduate enrollment is dropping, not only in our Department, but also in other MIT departments with which we share some common characteristics (i.e., Political Science, Economics, Architecture, and Civil Engineering). We do not read this as a market response to a weakness in our program. Rather, we see it as the direct result of MIT's undergraduate recruitment and admissions policies. We have a strong commitment to undergraduate education, but it means very little if we cannot attract undergraduate majors or concentrators. Overall undergraduate enrollment in Course XI subjects is up. This is the result, however, of renewed interest in the Urban Studies Humanities option and the pre-law and environmental studies subjects that we offer. We are still anxious to serve the 50 to 75 majors for which we planned several years ago. This year we had only 30 majors.

Finally, we still have not been able to develop firm ties to the Sloan School, the Energy Laboratory, and other engineering departments besides Civil Engineering. We have research and teaching interests in common with these other departments and centers. High on the list of Departmental objectives is a desire to find new ways of collaborating with our colleagues in these other areas of MIT.

Personnel Changes

There were six promotions this past year. Phil Clay was promoted from assistant to associate professor. Professors William Wheaton, Ferreira, and Hack were all granted tenure. Professors Marx and Gakenheimer were promoted from associate to full professors. There were also three departures from the faculty. Kent Colton accepted a professorship in public management at Brigham Young University; Rob Hollister became chairman of the Program in Urban, Social, and Environmental Policy at Tufts University; and Michael O'Hare assumed the post of Director of Policy Analysis for the Massachusetts Secretary of Environmental Affairs.

After an extensive search process, Raj Saah was appointed Ford International Assistant Professor of Urban Studies and Planning. Professor Saah will teach economic development theory and project analysis in developing countries. We also have made several temporary appointments for the coming year. Lynne Sagalyn will serve as Assistant Professor of Urban Studies and Planning and will be teaching in the housing field while Professor Solomon is on sabbatical. Valerie Nelson will serve as Visiting Assistant Professor of Urban Studies and Planning while Professor Minor is on leave. Martin Krieger will be Visiting Assistant Professor of Environmental Studies, and Evelyn Murphy will serve as Senior Lecturer in Environmental Studies while we conduct a search for Professor O'Hare's replacement.

LAWRENCE SUSSKIND

Laboratory of Architecture and Planning

The year 1979-80 was one of significant growth for the Laboratory of Architecture and Planning (LAP). The statistics reflect double last year's volume of activity generated by the staff and faculty working through the LAP; more than 80 faculty, staff, and students engaged in LAP activities; several thousand volumes distributed through the LAP's new Publications Program; and 150 practitioners enrolled in last summer's Continuing Education Program -- double the previous year's enrollment.

LAP OBJECTIVES

The research and special programs conducted through the LAP continue to serve its three broad objectives of furthering the state-of-the-art of practice and teaching in the fields of architecture and planning; linking the School with the activities of practice; and encouraging research about areas of emerging concern to society and the professions.

LAP projects concerned with energy and buildings illustrate how these objectives are comprehensively achieved. Sponsored research concerns both technology and policy. Principal Research Associate Timothy Johnson's work with Solar House V, funded by the Department of Energy (DOE), and Professor Douglas Mahone's collaborative work with the Energy Laboratory about building insulation, funded by private industry, are examples of projects which deal with technology. Work of Professor Michael O'Hare concerning residential energy conservation, funded by the State of Maryland, and work of LAP Director Michael Joroff, for the US National Park Service, regarding plans for energy conservation, are examples of policy-oriented research. LAP projects also deal with exploring new ways to teach about energy and design. For the second consecutive year, the LAP hosted the DOE/Association of Collegiate Schools of Architecture's Energy Design Institute for architectural faculty across the country. Funded by DOE, Professor Edward Allen is developing curriculum material for teaching about energy through the design studio; and Professor Mahone and LAP Director Joroff are preparing case study teaching material about energy-conscious design, funded by the National Endowment for the Arts (NEA). The LAP's continuing education course, "Design Techniques for Passive Solar Architecture," presented state-of-the-art information to the 50 practitioners who participated in the week-long program.

RESEARCH AND COMMUNITY PROJECTS

The following list of projects conducted through the LAP suggests the staff and faculty's significant breadth of interest as well as sustained concern about such topical issues as: environmental management, energy and buildings, neighborhoods, research methodology, regional analysis, adaptive housing and environmental design, and citizen participation in planning. Growing interest in such topics as the relationship between culture and built form, use of the media by public agencies, and new settlement patterns is also reflected.

The Environmental Impact Assessment project continues investigation of the ways in which public agencies can better project and assess environmental impacts of proposed policies, programs, and public investments. Professor Lawrence Susskind is the principal investigator.

The Environmental Mediation project explores techniques for mediating environmental disputes. Professor Susskind is the principal investigator, and the project is funded by the Environmental Protection Agency.

The study of Innovations in the Design Process of the National Park Service emphasizes organizational adaptations required to accommodate the National Park Service's new program of appropriate technology. LAP Director Joroff is the principal investigator, and the work is funded by the National Park Service.

Residential Energy Conservation is a study of the use of enforced disclosure of residential heating efficiency to encourage energy-conscious design as an alternative to regulatory control. Professor O'Hare is the principal investigator, and the work is funded by the State of Maryland.

MIT Solar House V, constructed on the MIT campus, demonstrates direct-gain solar space heat through the use of new architectural finishing materials. Mr. Johnson is the principal investigator, and the work is currently funded by the Department of Energy.

The Energy Conservation Building Project analyzes energy-conserving design options for large buildings. Professor Mahone is collaborating with the Energy Lab on work funded by the MIT Cabot Fund and private industry.

The Determinants of Housing Choice Among Elderly project analyzes the strategic personal and institutional issues which affect the decisions of aging people to move or stay in their residences. Professor Sandra Howell is the principal investigator, and the work is funded by the Administration on Aging.

The Design Collaborative for Supportive Environments is a program which provides research-cum-consultation services to institutions and organizations which seek to adapt physical environments to meet the needs of populations with special needs. LAP Director Joroff is the principal investigator, and the work is funded by various sources, including the Massachusetts Department of Mental Health.

The study of Urban Patterns of Change describes the growth of San Francisco, and the influence of zoning and public policy on changes in land, building, and open space patterns. Professor Anne Vernez is the principal investigator, and the work is funded by the NEA.

The study on Firm Behavior as a Determinant of Economic Change attempts to understand how employment changes take place. The project focuses on the micro-level to explain change in terms of the activities of individual establishments. Senior Research Scientist David Birch is the principal investigator, and the work is funded by the Department of Commerce.

Relating Transportation to Neighborhood Change is a project to assess the effects of changes in transportation technology and energy costs on neighborhoods. Dr. Birch is the principal investigator, and the work is funded by the Department of Transportation.

Economic Role of Small Businesses is a study to analyze the role that small businesses play in creating jobs and bringing about economic change. Dr. Birch is the principal investigator, and the work is funded by the Small Business Administration.

The Energy and Neighborhood Development project analyzes the impact of changing energy supply and cost on the development of neighborhoods. Dr. Birch is the principal investigator, and the work is funded by the Department of Energy.

The National Employment Shifts project is a study of how aggregate employment changes in different parts of the country are caused by the behavior of individual firms. Dr. Birch is the principal investigator, and the work is funded by the Department of Commerce.

The project on General Model for Analysis of Small Business Development is developing generalized models for small-scale analysis. Dr. Birch is the principal investigator, and the work is funded by the Dun and Bradstreet Corporation.

The Consistent System project continues to develop a large collection of applications software for data management and data analysis. Principal Research Scientist John Klensin is the principal investigator, and the work is funded by various sources.

Management of Large-Scale Data Files for Community Development is a project to design a software system to serve local government planning needs. Principal Research Scientist Klensin is the principal investigator, and the work is funded by the Massachusetts Department of Community Affairs.

The Architecture Case Studies Program is now preparing two series of cases. One focuses on environmental design for special needs populations, the other series focuses on issues concerning energy-conscious design. LAP Director Joroff and Professor Mahone are the principal investigators, and the work is funded by the Association of Collegiate Schools of Architecture, the NEA, and other sources.

The Citizen Involvement in the Budget Process project provides analytic, technical, and organizational support to citizen task forces working to determine how government funds can be allocated to social service needs. Citizen task forces are assisted in mediation efforts with town selectmen. Professor Susskind is the principal investigator, and the work is funded by the Town of Arlington, Massachusetts.

The Boston Neighborhood Network is an innovative project which attempts to make university-based research useful to the leadership of neighborhood organizations. The Network presents workshops, seminars, and conferences about diverse subjects, such as mortgage lending patterns, use of appropriate technology, and social indicators as a tool for guiding neighborhood development. Visiting Professor Hollister is the principal investigator, and the work is funded by the National Science Foundation.

The LAP now serves as the overall administrative home for the new Aga Khan Program in Islamic Architecture. In addition to professorships which will be located in the Department of Architecture and a documentation project centered in the Rotch Library, there will be summer institutes, a faculty exchange program, and other activities to strengthen the program and link it with its counterpart program at Harvard, with other programs here at MIT, and with other institutions and individuals throughout the world. Dean William Porter is the Program's coordinator.

DISSEMINATION OF RESEARCH FINDINGS

The LAP remains committed to disseminate the findings of research to as wide a professional and public audience as possible. The Publications Program, which now offers 40 titles, is designed to serve this objective. *The Environmental Impact Assessment Review* is published by the Plenum Press, and edited by staff from the Department of Urban Studies and Planning and from the LAP. Professor Susskind is the *Review's* senior editor. The Boston Neighborhood Network is designed specifically to build the same kinds of long-term communication among university personnel, community leaders, and local government program staff as university researchers now have with colleagues in government, industry, and other universities. Included on the LAP's staff are professionals with considerable experience using the electronic and print media. They work with LAP researchers to shape effective dissemination strategies to reach a broad public as well as professional audience. One effort this year resulted in a three-part news series about an environmental issue which was aired on WGBH-TV. This was produced by LAP Affiliate Thomas Piper.

STAFF AND COLLABORATIVE ARRANGEMENTS

The LAP core research and administrative staff continues to be strengthened. Donna M.T. Herlehy, formerly an assistant director of the Office of Sponsored Programs (OSP), joined the LAP as Administrative Officer; and Sharon Trohon, also formerly of OSP, joined the LAP as senior Administrative Assistant.

Research Associates appointed to the LAP this year include: Rebecca R. Packard, who serves as editor of the *Environmental Impact Assessment Review*, and as a core member of the LAP's Architecture Case Studies Project staff. Ms. Packard designed and directs the LAP's Publications Program.

Dejia Gallinaro is the Project Director for the Administration on Aging-funded project about housing choices made by the elderly.

Charles Knuth is assigned to MIT by the National Park Service as a member of the Cooperative Parks Study Unit (CPSU). Deborah Cramer and Rurik Eckstrom, also joined the LAP's CPSU staff.

Continuing on the LAP staff are Senior Research Scientist Birch, Principal Research Scientist Klensin, and Research Associate William Parsons. William Ronco continues to direct the LAP's Continuing Education Program. Lois Craig, a Principal Research Associate of the LAP, became the new Associate Dean of the School.

Dr. Judith Johnston, a Harkness Fellow from New Zealand, was a Visiting Scholar for a second year. Robert Whittlesey, formerly the Master to the Court for the Boston Housing Authority case, became a Research Affiliate of the LAP. Other Research Affiliates were: Mr. Piper, who does much of the LAP's video work, and Mark Walch who participates in the LAP's case studies program.

The LAP continues to extend its breadth of involvement in projects through collaboration with a variety of organizations. The LAP is formally collaborating with the MIT Energy Laboratory to initiate a new Institute program concerned with issues of conservation in buildings.

This year, the LAP completed arrangements with the US National Park Service to create a Cooperative Parks Study Unit (CPSU) at MIT to carry out a five-year research effort to focus on energy-conscious design and application of appropriate technology in the nation's national parks.

LAP projects currently involve formal collaborative arrangements with researchers in more than a dozen universities. The LAP is an active member of the Architectural Research Centers Consortium (ARCC), which represents and promotes collaboration among the 20 major university-based research centers. The LAP Director is ARCC's Vice President/President-Elect.

The LAP continues to enjoy excellent collaborative relations with the Harvard Graduate School of Design's Office of Special Programs with whom we offer our Continuing Education Program. We are now exploring ways to develop a national institute for the management of design firms.

SPECIAL PROGRAMS

The LAP continues to use its Continuing Education Program both as a means of providing a service to alumni and practitioners, and to promote the School's research agenda. Faculty and local professionals teach the courses. The courses offered during summer 1979 were: Passive Solar Energy -- Tools for Design Application (Professor Mahone); Planning for Neighborhood Change (Professors Hollister, Tunney Lee, Robert Yin); Environmental Design and Planning: An MIT Symposium (M. Elliot); the Planning Process (Professor T. Nutt-Powell); and Realities of Historic Preservation (R. Neiley).

In August 1979, the LAP hosted the Energy Design Institute of the Association of Collegiate Schools of Architecture. This Institute was an intensive week-long course for architectural faculty from schools throughout the country, and MIT faculty from the School of Engineering and Architecture played a major teaching role. During the latter part of the year, the LAP began planning for two major programs scheduled for the fall of 1980. One is the MIT day in the "Great Cities of the World Conference," the event which will climax the "Boston 350 Celebration." The School will host mayors and other visitors from 40 countries. Presentations and panel sessions will focus on the way in which city form and plans evolve to reflect their cultural context. The LAP is also working with faculty of the Department of Architecture to plan a symposium entitled, "Housing and Human Settlements: Looking Ahead into the 80s." The focus of this meeting will be on an exploration of new approaches to the many emerging problems facing the nations of Latin America and the US in planning, finance, management, and technology utilization in the fields of housing and human settlements.

DEVELOPMENT PLANS

With continued guidance from the School Council, the LAP works with senior faculty of the Departments of Architecture and Urban Studies and Planning to shape and implement a research agenda for the School. We are developing concerted strategies to foster increased faculty participation in research; make effective use of seed money; and develop the LAP's research staff. These matters will receive increasing attention in the coming year as the School moves to consolidate and augment its research capability. Advice about our research agenda is sought from practitioners in the field, members of the School's Visiting Committee, and representatives of client organizations.

MICHAEL L. JOROFF

School of Engineering

Academic year 1979-80 was the first complete academic cycle for the new members of the Dean's Office. It was a very exciting and rewarding year which could be characterized by new solutions being applied to existing problems.

In the overview, the number of undergraduates enrolled during the past academic year increased by approximately 1 percent. This confirms the pattern of the slowing trend in the rate of increase of the School. In the 1978-79 academic year, the total increase for all Departments within the School was 3 percent. In the previous three years, the growth rate was 10 percent or greater per year. The leveling trend which was predicted last year will probably be seen in the 1980-81 academic year. Once again, dramatic gains were made in enrollment by Electrical Engineering and Computer Science and Chemical Engineering.

Graduate enrollments in engineering increased by approximately 5 percent to a total of 1,843. This represents approximately 48.5 percent of the total graduate school population at MIT. Foreign students as a percentage of the total graduate population are holding fairly steady but are found more dominantly within the Ph.D. programs as opposed to the Masters or Engineers.

Fierce competition with other universities and private industry has kept the faculty size fairly constant. There are currently about 340 members of the School of Engineering faculty. The Departments within the School have been working diligently in order to increase this number by approximately 10. The number of extremely high caliber individuals holding advanced degrees in engineering are relatively few and the competition for them is intense. The major competitor for MIT seems to be private industry where extremely large salaries and benefits packages seem to be the attraction. Over the past year, several relationships have been developed which have turned some of this competition into cooperation. A design has been devised which will foster an informal relationship between a specific industrial organization and a newly appointed assistant professor. This encourages a good outside professional relationship between the individual and the organization, brings more real-world problems into the laboratory at MIT, allows the individual the latitude and academic freedom to pursue topics which may be germane to that industry, and to realize personal objectives in an academic career without undue financial sacrifice. This type of relationship has been developed with a number of organizations to include Detroit Diesel Allison Division of General Motors and American Can. The companies are contributing funds to at least partially defray the cost of supporting the individual assistant professor's salary. To date, the individuals, participating organizations, and departments seem pleased with the way the relationships are developing. Because of this type of relationship, we can afford to increase the faculty by use of funds which were liberated under these new support programs. These appointments are being tested on a three-year basis.

Given the current student enrollment, the projected optimal faculty size is approximately 350. The fact that we have not been able to achieve our full complement of faculty and yet maintain the quality of our education is a tribute to the energy and dedication of our faculty.

ENGINEERING INTERNSHIP PROGRAM

This completes the third year of operation of the School of Engineering Internship Program under the direction of John Martuccelli. This Program combines traditional on-campus academic experience with off-campus exposure to industry and government. It is designed principally for undergraduates who are oriented towards achieving the Bachelors and Masters simultaneously.

The third year was projected to be the year during which the Program reached a steady state. This year the projections for enrollment and company participants exceeded that which was originally estimated. For the summer of 1980, 60 sophomores have been placed into 33 participating companies. Last year, 43 sophomores were placed into 22 companies. Optimally, the Program should not increase much beyond its current level. We feel that it is essential to keep the Program relatively small to ensure the quality of the student for the company and the quality of the experience for the student. It is anticipated that a few more companies will be added during the next academic year. The purpose for this will be to achieve a better distribution of types of assignments and organizations.

The 33 companies currently participating in the Program are: Aerospace Corporation, American Can Company, Avco Systems Division, Barkan Construction Company, Boeing Vertol Company, Boston & Main Railroad, Brookhaven National Laboratory, Brown & Root, Inc., Chrysler Corporation, Combustion Engineering, Inc., Commonwealth Edison Company, Computervision Corporation, C.S. Draper Laboratory, Inc., EG&G Idaho, Inc., General Electric (and its Space Division, Reentry & Environmental Systems Division, Research & Development Center), General Motors Corporation, Grumman Aerospace Corporation, Hughes Aircraft Company, International Harvester Company, Lincoln Laboratory, National Aviation Facilities Experimental Center, Northrop Corporation, Philips Laboratories, Sikorsky Aircraft Company, Stone & Webster Engineering Corporation, The Timken Company, Transportation Systems Center, Westvaco Corporation, Weyerhaeuser Company, Yankee Atomic Electric Company. In keeping with the procedures set up in the summer of 1978, each of the 33 participating companies will be visited this summer by the companies' faculty representative (a faculty member is assigned to each company to provide a liaison among the company, the students, and MIT) and the administration of the Engineering Internship Program.

COMMITTEE ON ENGINEERING EDUCATION

The Committee on Engineering Education (CEE), chaired by Professor James W. Mar, Jerome Clarke Hunsaker Professor of Aerospace Education, was actively engaged in a number of studies and enterprises throughout the past academic year. Among other things, they published an issue of the CEE Newsletter and held an open hearing on March 12, 1980 in order to obtain ideas relative to engineering and human affairs. The work of the Committee has been exciting and the members have found that as soon as one issue is dealt with, several more present themselves for consideration. The Committee again sponsored the Freshman Seminar, "What is Engineering?"

The CEE is also in the process of completing an energy brochure which cross-references subjects and research projects with different types of energy production and consumption. This brochure will be distributed to faculty and students within the School of Engineering. The Committee is also working with members of the School of Science in an attempt to slightly modify some of the core subjects in mathematics, physics, and chemistry. Dean Robert Alberty of the School of Science chairs a "core" committee on which the Committee on Engineering Education as well as other constituencies of the Engineering School are represented. The Writing Program has been extremely successful over the past year, both on the undergraduate and graduate level. Within the context of the undergraduate studies, the Program has spread to core engineering subjects within all departments of the School. On the graduate level, the Writing Program is involved with five departments. As more time and resources become available, this Program will be implemented in the remaining three departments.

MANAGEMENT OF ENGINEERING

Over the past academic year, the Sloan School of Management and the School of Engineering have designed and are prepared to implement a Program in the Management of Technology. This academic Program is aimed at the graduate education level, granting the S.M. degree to individuals with engineering and scientific backgrounds who, because of the evolution of their career

paths, need to develop the skills to translate between management and engineering. The type of individual who will be a candidate for this degree will have between five and ten years' experience as a practicing engineer or scientist and who intends to return to that particular discipline in a manager capacity. The Program Committee for this inter-school initiative is co-chaired by Edward Roberts, David Sarnoff Professor of Management, and Professor Kent Hansen, Associate Dean, School of Engineering. The Program co-chairmen are currently in the process of selecting a professional manager who will be charged with the responsibility of implementing the Program Committee's policy and bringing the Program to full enrollment.

SCHOOL APPOINTMENTS

During the past academic year, Professor Ira Dyer, Department Head of the Department of Ocean Engineering, was on sabbatical leave. During his absence, Professor J. Nicholas Newman was appointed Acting Department Head.

In December 1979, Professor J. Herbert Hollomon, Director of the Center for Policy Alternatives, became seriously ill. Following a convalescent leave, Professor Hollomon was able to resume his activities as Center Director in May of this year. In his absence, Professor James Utterback assumed the post of Acting Director.

Commencing in June of this year, Professor Walter Owen, Head of the Department of Materials Science and Engineering, was granted a six-month sabbatical leave. During his absence, Professor Bernhardt J. Wuensch assumed the post of Acting Department Head.

During the past academic year, MIT announced the formation of the Materials Processing Center. Under the direction of Merton C. Flemings, Ford Professor of Engineering, the Center has achieved interdepartmental status.

Also during the past year, the creation of the Laboratory for Manufacturing and Productivity was formalized under the direction of Professor Nam P. Suh of the Department of Mechanical Engineering.

As of July 1, 1980, Professor Frank Perkins resigned as the Head of the Department of Civil Engineering. Professor Perkins has accepted the position as Associate Provost and will commence his duties as of July 1, 1980. Professor Kenneth A. Smith of the Department of Chemical Engineering will also assume the post of Associate Provost, effective July 1, 1980.

ROBERT C. SEAMANS, JR.

Department of Aeronautics and Astronautics

Undergraduate enrollment in the Department continues to increase. This year there were 41 seniors, 48 juniors, and 69 sophomores from Course 16, plus some six from outside the Department enrolled in Unified Engineering. Approximately 80 Course 16 sophomores are projected for the 1980-81 year, bringing the Department's undergraduate class close to its peak of the 1960-70 period.

To maintain its standards for personal interaction between students and faculty, and to accommodate the rising demand for undergraduate participation in research, the addition of new young faculty members was identified as a major objective for the past year. We have had considerable success in this area with five new assistant professors having been appointed this year or for the coming year.

Fortunately, the Department has been aided in this expansion by the creation of the Draper Career Development Professorships, and by endowment of the Boeing Career Development Professorships by the Boeing Company. Each of these chairs supports two assistant professors. A fifth assistant professor is funded by Detroit Diesel Allison Division of General Motors in the area of small gas turbines with emphasis on ceramics.

The initiative in Computational Fluid Dynamics begun last year has been continued with the addition to the faculty of Professor Earl Murman, a recognized leader in this field. NASA has designated MIT as one of seven universities to receive grants for curriculum development and graduate student support in this area of growing importance to aerospace engineering. In the coming year the Department's program will involve four faculty.

Within an expanding undergraduate population and increased undergraduate research activities, classroom space and undergraduate laboratory facilities and staff are severely taxed. A technical instructor with experience in digital electronics has been added, and improved use is being made of available space, but there remains a need for better equipment and more appropriate laboratory space for undergraduate laboratories.

Graduate enrollment has not expanded along with the undergraduate classes. Competition from the excellent job opportunities experienced by four-year graduates appears to be a major factor in the undersupply of graduate students, from which MIT suffers somewhat less than most engineering schools.

Undergraduate Program

Unified Engineering has continued to serve well as the student's introduction to the disciplines and approaches of aerospace engineering. It brings a sense of community to the sophomores and faculty which is very helpful to the development of a student's potential. This year the subject was organized by Professor Shaoul Ezekiel, who also lectured in dynamics. Other lecturers were Professors Leon Trilling, John Dugundji, Harold Wachman, Associate Professor Manuel Martinez-Sanchez, Professors Philip Whitaker and René Miller. Most also taught tutorial sessions in which the faculty assisted the students with all the subject matter and problems. Each semester is capped by a banquet at which comments, both favorable and otherwise, are solicited. Most students view Unified Engineering as a rigorous experience, demanding, but worthwhile. The faculty perceive a noticeable improvement in the students' performance, both in more advanced undergraduate subjects and in research activities. This year the attrition due to lack of academic performance was small. We regard Unified Engineering as a success and will continue to refine it.

The Undergraduate Projects Laboratory is a major focus of experimental activity for undergraduates. Each student has in the past registered for a one-semester subject (16.62) in which, under the supervision of a faculty member, he or she proposes, designs, constructs, operates, and reports on an experimental research project. The subject was organized this year by Professor Winston Markey. Allan Shaw supervises the Laboratory, assisted by Technical Instructors Donald Weiner and Robert Renshaw. Other Departmental staff, including Albert Supple, Earle Wassmouth, and Fred Merlis, are available to add technical support as requested by Mr. Shaw.

With some 50 students per year conducting individual projects, this is a major activity; and as the undergraduate classes grow it will become increasingly difficult to accommodate the students in the existing facilities. Equipment is being updated, but more space will be necessary as well.

The objectives of the Laboratory are ambitious: not all students have been successful in meeting them within a single semester. To alleviate this problem and raise the general level of performance, the Laboratory has been modified for next year to a two-semester sequence. In the first (three unit) semester the student will be expected to conceive, plan, and propose a project. If it is approved, acquisition of long-lead-time apparatus and parts will be initiated. During the second (12 unit) subject the project will be carried through and reported. It is hoped that this will enable the students to take better advantage of this important experimental effort, which is entirely new to most.

The Avionics Option (Course 16-2) organized by Associate Professor Walter Hollister has proved to be popular, enrolling a total of 14 students this year. It enables them to achieve considerable depth in electronics, while retaining breadth of exposure to aerospace engineering. Opportunities in this area are being expanded with the creation by Professor William Widnall and his students of a Microprocessor Laboratory, which will provide undergraduates with facilities for application of microprocessors to the real-time-control of mechanical systems. Assistant Professor John Thomas will collaborate in this work in the coming year.

Under the leadership of Professor Emmett Witmer the Undergraduate Committee has reviewed the undergraduate programs. This review has led to the restructuring of the Undergraduate Projects Laboratory described above, to the reaffirmation of 8.03 as an important part of the Course 16 curriculum, and to recognition of the need for advanced undergraduate subjects in dynamics and in heat and mass transfer. Such subjects are now in the design stage.

UROP activities have become a very important part of the Course 16 curriculum. While they draw on the sponsored research programs, these activities also depend heavily on support from the Undergraduate Projects Laboratory. As will be noted below, the UROP activities in the Space Systems Laboratory directed by Professors Mar and Miller involve the largest single group of students (32) at the Institute.

Graduate Program

Graduate enrollment has remained level at 150, of whom approximately half are S.M. and half doctoral candidates. It is constrained more by the number of qualified candidates than by financial support or by faculty supervision, although as usual the distribution of students over faculty is uneven, leading to some very large loads. Professor Wallace Vander Velde served as chairman of some 13 doctoral committees in the popular area of modern control. Of the highly qualified US applicants, all of whom have or are offered fellowships or research assistantships, about half elect to come. This must be regarded as success since all such students also apply to at least one other school, such as the California Institute of Technology, Stanford, or Princeton. It is the pool which is small at present both because of competition from the expanding aerospace industry and the small sizes of recent undergraduate classes in aerospace engineering.

There is a continued high demand for places in the graduate school from foreign students, many with excellent qualifications. As in the past, we have carefully selected our students to maintain a balance between foreign and US students. It should be noted that many foreign graduate students ultimately remain in the US, particularly those who receive doctoral degrees.

Graduate subject offerings continually undergo revisions, deletions, and additions. This year Professor Judson Baron offered a new subject, 16.025 Introduction to Numerical Aerodynamics which drew 18 students. Assistant Professor William T. Thompkins offered 16.542 Advanced Computational Methods in Internal Flows which was also well attended. A seminar subject in Aircraft Engine Structures was taught by a group of faculty led by W.T. Thompkins and Donald Jordan. This will be offered as a regular subject next year by Assistant Professor Edward Crawley.

The subject in Satellite Engineering (16.851) begun last year was continued this year largely by Associate Professor Hollister, with assistance from Dr. Raymond L. Bisplinghoff.

A new subject, Quantitative Models in Transportation Planning, has been designed by Professor Amedeo Odoni and will be offered in the coming year.

Assistant Professor Robert Kenyon offered Biomedical Signal Processing (16.345J, HST-852J) in cooperation with the Harvard-MIT Health Sciences and Technology Program. He also participated in planning a new subject in Flight Simulation (16.36) to be offered next year.

Professor Giuseppe Colombo, Visiting Hunsaker Professor for the spring semester, offered 16.86 Space Systems Engineering with the theme of utilization of tethers to improve the payload of the Space Shuttle.

RESEARCH

Sponsored research under the supervision of faculty members in the Department of Aeronautics and Astronautics was funded at a level of about \$5 million for the past year, of which 33 percent was derived from NASA grants and contracts, 33 percent from the US Air Force, 20 percent from other Federal agencies and the remainder from miscellaneous sources. There was substantial funding from industry, particularly for research on aircraft gas turbines.

Nearly all research involves graduate and undergraduate students, under the supervision of faculty and a few staff members. One large group of graduate students conducts research at the Charles Stark Draper Laboratory, some under the supervision of several Draper staff members who are designated as thesis supervisors, and some under faculty supervision. Professor Whitaker and Professor Vander Velde are active in the latter way.

Because of its success in involving UROP students in its sponsored research programs, the structure of the Space Systems Laboratory is of special interest and will be described.

The Laboratory is organized around a series of projects with the common theme, "Engineering for Space Utilization." It is concerned more with the development of the resources of space to improve the quality of life on earth than with space exploration and space science.

There are several projects such as Orbital Productivity and Structures in Space. Associated with each project are several research topics. Each topic is led by a group leader selected from among the student staff of the Laboratory. The group leader is generally, but not always, a graduate student. The Laboratory is under the general direction of Professors Mar and Miller, who are responsible for the overall administration and funding of the Laboratory, in addition to being involved in most of the research projects. A faculty supervisor is associated with each project, and there are six faculty supervisors.

It is important to recognize that although each project appears to be a separate entity, they are in effect closely coupled. Interaction between the various researchers, migration from each task to another, and general participation in the Laboratory's activities are encouraged. To facilitate this communication the student personnel of the Space Systems Laboratory are located in a large open area, and all members of the Laboratory are urged to make this their base, and conduct as much of their work as possible in the Laboratory area.

There are several reasons for the somewhat unusual (for an academic institution) organization of Laboratory activities. The primary purpose is to expose each student to the experience of working as a team member. Most academic work involves an individual effort and it is therefore important for students to experience the group effort that is characteristic of all engineering projects. It is also important to gain experience in directing the efforts of others, administering projects, meeting schedules, and preparing progress and final reports.

The work of the Laboratory is published in report form as SSL archival documents. This work may also appear as part of published papers, theses, or reprints for professional meetings, but is always available as numbered SSL reports. These reports are necessary not only as a matter of record for future research, but as a reporting mechanism to satisfy the Laboratory's contractual obligations.

During the past year a highly successful series of tests were conducted in the NASA Marshall Space Center Neutral Buoyancy Facility. These tests substantiated the results of previous experiments in the MIT pool, where the weightless environment was simulated during assembly of typical space structures. The tests at the Marshall Space Center were conducted with subjects in space suits. Although suiting reduced productivity by a factor of 2, the final productivities were an order of magnitude higher than for similar assemblies in a gravitational environment. Learning curves were established and showed typical slopes of the order of 80 percent.

Activities continue to expand in the Gas Turbine and Plasma Dynamics Laboratory, of which Professor Eugene Covert is now director. This year a multi-investigator grant for research on turbomachinery fluid mechanics was obtained from the Air Force Office of Scientific Research. Under the supervision of Associate Professor Edward M. Greitzer this \$500,000 grant supports

work on transonic compressors, on stall and surge phenomena, and on inlet vortex effects. Under NASA sponsorship the Laboratory has studied the flow in two advanced transonic compressor stages and has undertaken the design of an improved compressor rotor.

In the Aeroelastic and Structures Laboratory, Professor Witmer has developed finite element codes for predicting containment of jet engine rotor fragments. The codes are in use by industry.

Professor Norman D. Ham and his students working in the VTOL Technology Laboratory have studied means for individual blade control on helicopters. Such control would reduce gust and vibration loads by control of the blade pitch in response to excitations.

The Flight Transportation Laboratory, directed by Professor Robert W. Simpson, is conducting research on pilot workload, on automated decision making for terminal area air traffic control, on air traffic control simulation facilities, and a number of other subjects. It involves a large number of graduate students (about 35) in this rapidly expanding area of research. There are now three full-time faculty members available for supervision of these 35 graduate students, many of whom are self-supporting foreign nationals. Five part-time lecturers help with the instruction, but the faculty load of thesis supervision is heavy.

A seven-week summer program sponsored by the International Civil Aviation Organization (ICAO) was held in June and July 1979, and was attended by 15 students from the Middle East, Africa, and Latin America. These students were senior executives in civil aviation, responsible for the future development of airports, airlines, and air traffic control systems in their countries. The FTL Airline Management Game, developed by Professor Elias, was used for academic purposes for the first time. The course will be repeated this summer with 30 students. Charles Cary, Professor Simpson, and John Wiley traveled to Manila in January 1980 to give a four-week version of the course at the new Civil Aviation Training Center under ICAO/United Nations Development Program funding. The Laboratory was approached by Iraq, Colombia, and Brazil for similar courses to be held abroad, but we had to refuse.

Through the Aerophysics Laboratory, the Department has responsibility for the design of superconducting coils for a magnetic suspension system for the National Transonic Facility (wind tunnel) being built at NASA Langley Research Center. Professor Covert and Dr. Charles Haldeman collaborate on this program.

Professors Leon Trilling and Harold Wachman, and Mr. David Dreyfuss have developed a new technique for measurement of the size and velocity of water vapor clusters, which opens a new avenue for study of nucleation.

In the Technology Laboratory for Advanced Composites (TELAC) directed by Professor Mar, four doctoral students, six S.M. candidates, and 19 UROP students conduct research on fracture and fatigue of these materials. They are beginning studies of the structural dynamics of graphite/epoxy shafts, of the damage tolerance of fuselage structures, and of the behavior of unsymmetric laminates. They also are examining the fabrication of graphite/epoxy members for large space structures.

The MIT Innovation Center was formed in 1973 with National Science Foundation funding as an experiment in innovation education. It continued this year under the direction of Associate Professor David G. Jansson, with the collaboration of several other faculty members of the Department and of the Engineering School.

The Innovation Center offers two classroom subjects in its educational program: a graduate/undergraduate subject on invention and a graduate/undergraduate subject on entrepreneurship. About 90 students participated in these two subjects during the past year, the major part of this group being graduate students from the engineering departments.

The principal area of research includes the development of an invention evaluation methodology, investigation of ways to develop human resources to improve the innovation base for energy-related technology, and work on commercialization of energy-related inventions. This effort has been sponsored by the National Bureau of Standards and the Department of Energy. Eight research assistants have participated in the research.

The product development activity of the Innovation Center has included four projects during this past year. Three undergraduate students, one graduate student, two part-time staff members, and three visiting scholars have been involved in this work under the guidance of four faculty members.

The total funding level for this past year was approximately \$350,000. Nine faculty members have contributed to the various activities of the Center.

FACULTY

Two Draper Assistant Professors were appointed this year. Dr. Michael Bowles' appointment was effective February 1, 1980. He plans to teach and work in estimation and control. Dr. John Thomas, whose appointment will be effective July 1, will work on lasers and optics, and also in applications of microprocessors.

The Boeing Career Development Professorships became available during the spring semester. Dr. Antonio Elias has accepted one of these positions and will teach and conduct research on Flight Transportation. Edward F. Crawley will become the second Boeing Assistant Professor in September. His interests are aircraft engine structures and space engineering.

Dr. Alan H. Epstein will become Assistant Professor of Aeronautics and Astronautics July 1, 1980. With Associate Professor Roland Cannon of Materials Science and Engineering, he will offer a subject in ceramic applications to gas turbines. He will also offer a new subject in advanced instrumentation techniques.

Dr. Earll Murman, formerly Vice President of Flow Research Company, has accepted a position as Professor of Aeronautics and Astronautics, effective September 1980. He will teach and do research in applications of computational fluid dynamics to aerospace engineering.

Associate Professor Amedeo Odoni has been promoted to Professor of Aeronautics and Astronautics effective July 1, 1980.

Associate Professor Manuel Martinez-Sanchez has been granted tenure effective July 1, 1980.

Dr. Giuseppe Colombo, of the University of Padova, Italy, was Hunsaker Visiting Professor for the spring semester. He guided a Space Systems Engineering (16.86) group in study of a concept for improving the productivity of the Space Shuttle by use of a large orbiting platform in which payloads would be transferred from the Shuttle by a tether. He also delivered the 16th Minta Martin Lecture, entitled "Evolution of Space Technology: Fiction Versus Reality."

The Department was pleased to welcome Associate Professor Wesley Harris to full-time teaching and research upon his return from a year spent as Manager of Computational Fluid Dynamics in NASA Headquarters. Previously Professor Harris held a joint appointment with Ocean Engineering.

Associate Professor Nicolas Garcia-Garcia of Universidad Autonoma de Madrid, has joined the Department as Visiting Associate Professor of Aeronautics and Astronautics. He will work in the molecular beam area with Professors Trilling and Wachman.

Associate Professor Atsuhiko Noda of Tokyo Institute of Technology is Visiting Associate Professor of Aeronautics and Astronautics. He will be conducting research in the Man-Vehicle Laboratory with Professor Laurence Young.

Dr. Aleksei Krutov, of Moscow, USSR, an IREX Scholar, was in residence in the Department this year, working with Adjunct Professor Richard Battin.

We were pleased to have four Visiting Scholars from the People's Republic of China studying and conducting research in the Department this year. Da-peng Chen worked with Professor Pian on finite element methods. Zu Wei Huang participated in the activities of the Space Systems

Laboratory. Jun He worked in the field of optimal control of spacecraft with Professor Vander Velde. Qidong Yang worked in the Innovation Center's 30 graphic display device project with Professor David Jansson.

Five staff members of the Draper Laboratory who have been active in guiding thesis work by Draper Fellows have been designated Draper Associates. This indicates that they are recognized by the Department as doctoral thesis chairmen. They are Dr. Donald Fraser, Dr. Albert Hopkins, Dr. Paul J. Cefola, Dr. John Deyst, and Dr. R. Ramnath.

Professor Yao Tsu Li retired from full-time service this year after 33 years as an MIT faculty member. He will continue to be active in the Innovation Center as a Senior Lecturer.

Honors

In recognition of his contributions to the Department and to the Institute, Professor James W. Mar was named Hunsaker Professor of Aerospace Education.

The Department was especially pleased that three of its faculty, Professor K.U. Ingard, Professor Covert, and Professor L. Young were elected to the National Academy of Engineering.

Professor R. H. Miller was elected an Honorary Fellow of the American Institute of Aeronautics and Astronautics.

Professor Sheila Widnall, currently serving as Chairman of the MIT faculty, has been elected Chairman of the Board of Visitors of the Air Force Academy, a Board to which she was appointed by President Jimmy Carter.

Professor K. Uno Ingard was one of 10 leading scientists and engineers from throughout the world who received honorary doctoral degrees from Chalmers University of Technology in Gothenburg, Sweden, in November 1979.

Professor Jack L. Kerrebrock delivered the Dryden Research Lecture to the American Institute of Aeronautics and Astronautics (AIAA). The title was, "Flow in Transonic Compressors."

Associate Professor Edward M. Greitzer was selected by the American Society of Mechanical Engineers for its Freeman Scholar Award in Fluids Engineering. His survey is entitled, "The Stability of Pumping Systems."

Associate Professor Wesley L. Harris has been appointed to the US Army Science Board.

Professor Laurence R. Young has been appointed to the Air Force Scientific Advisory Board. He also has been elected a Fellow of the Explorers Club.

Special Activities

Professor T.H.H. Pian was invited to present a summer course in finite element methods at two universities in Beijing, China: the Beijing Institute of Aeronautics and Astronautics, and the Beijing Institute of Technology.

Professor James W. Mar served on the FAA advisory committee appointed to deal with the DC-10 accident which occurred in the summer of 1979. Three of the four members of the committee were or had been associated with the MIT Aeroelastic Laboratory. He is also a member of the committee on the FAA Airworthiness Certification Procedures formed by the National Academy of Sciences as a result of the same incident.

Professor Covert chairs the Space Shuttle Main Engine Advisory Committee of the National Academy of Sciences, and is vice chairman of the Air Force Scientific Advisory Board.

Professor Jean F. Louis is program chairman of the Seventh International Conference on MHD Electrical Power Generation, to be held at MIT June 16-22, 1980.

Professor Shaoul Ezekiel lectured on various aspects of lasers and their applications in Germany, Russia, the People's Republic of China, and Brazil. He serves as associate editor of *Optical Engineering*.

Professors Simpson and Odoni, and Dr. Taneja all participated in the work of the Transportation Research Board of the National Academy of Engineering. Professor Simpson also chaired the advisory panel for a study of "Impact of Advanced Air Transport Technology" by the Office of Technology Assessment, and was a member of the Air Transport Committee of the International Chamber of Commerce.

Professor Odoni served as associate editor of the *Journal of Aircraft* of the AIAA.

Associate Professor Walter Hollister is a Director of the New England Section of AIAA and a member of the Guidance and Control Panel of the Advisory Group for Aerospace Research and Development.

JACK KERREBROCK

Department of Chemical Engineering

Departmental activities increased again to higher levels during the past year. Larger enrollment and expanded research activity placed heavy demands on faculty and laboratory facilities. The Department continues to have the highest ratio of students to faculty of any department in the Institute. The excellent response of the faculty to these demands maintained the high standards set by the Department.

Undergraduate Program

Undergraduate enrollment increased to 335 students from the previous total of 318. A combination of lecture presentations and multiple recitation sections for core subjects accommodated the large classes and continued to provide effective student-faculty interaction. The following table shows the trends in undergraduate enrollment.

	<u>Undergraduate Enrollment</u>				
	<u>1975-76</u>	<u>1976-77</u>	<u>1977-78</u>	<u>1978-79</u>	<u>1979-80</u>
Sophomore	79	103	107	98	107
Junior	60	97	106	114	111
Senior	<u>45</u>	<u>51*</u>	<u>99</u>	<u>106</u>	<u>117</u>
Total	184	251	312	318	335

* Does not include students in the five-year program who transferred to the graduate school.

A new curriculum for the Bachelor of Science in Chemical Engineering degree, with additional specified requirements in chemistry and in design and economics, became effective in 1979-80. A large fraction of the senior class took advantage of the new curriculum in selecting elective subjects.

A faculty committee headed by Professor Frederick A. Putnam directed the purchase and installation of a computer with many terminals for easy access by undergraduates and the enrichment of the undergraduate curriculum with more computer usage.

Graduate Program

Graduate enrollment increased to 228 full-time students from the previous total of 202. Seventy-three students were enrolled in the doctoral program. Offers for graduates at all degree levels continued to be attractive. The following table shows the trends in graduate enrollment.

	<u>Graduate Enrollment</u>				
	<u>1975-76</u>	<u>1976-77</u>	<u>1977-78</u>	<u>1978-79</u>	<u>1979-80</u>
Total Graduate Students	163	181	185	202	228
Doctoral Students	46	49	70	74	73

Twenty-nine graduate students attended the Practice School Stations. One station is sponsored by the General Electric Company at the Silicone Products Department and the Plastics Department plants near Albany, N.Y. The other station is at the Oak Ridge National Laboratory. They complement each other to provide a wide range of experience in the practice of chemical engineering. The Visiting Committee endorsed the Departmental plan to revitalize the Practice School into an elite program, by making the student body more select and competitive and by supporting the Practice School students on a par with research students. "Friends of the Practice School" was

formed by members of the Visiting Committee, chaired by Jerry McAfee, Doctor of Science, Course X, Class of 1940 to raise resources for Practice School scholarships. Jefferson Tester, Doctor of Science, Course X, Class of 1971 was recruited to be the next Director of the Practice School, replacing Professor J. Edward Vivian who is retiring.

FACULTY

The Warren K. Lewis Lecturer was Dr. Ralph Landau of Halcon, International, who spoke on "Innovations in the Chemical Processing Industry." The Visiting Faculty Lecture Series, organized by Professor Christos Georgakis, included the following lecturers: Professor G.F. Froment of Rijksuniversiteit-Gent, Belgium; Sir W.R. Hawthorne, Cambridge University; Professor C.W. Macosko, University of Minnesota; Professor A.C. Payatakis, University of Houston; Dr. R.E. Rosensweig, Exxon Research and Engineering Co.; Professor W.B. Russel, Princeton University; Professor W.J. Thomas, University of Bath, U.K.; Dr. V.W. Weekman, Mobil Oil Corp.; and Professor W. Henry Weinberg, California Institute of Technology. Professors Georgakis, Edward W. Merrill, Robert C. Reid, and Selim Senkan of our Department also participated in the series.

Professor James Wei, Department Head, is a member of the Diesel Impact Studies Committee and a member of the Technology Panel for the National Research Council. He served on a synthetic fuels committee for the National Academy of Engineering. He is promoting university/industry cooperation by serving as a task force member of the Conference on Cooperative Advances in Chemical Science and Technology. The assigned task is to develop a Chemical Research Institute which would raise funds from chemical companies to fund university research. Professor Wei also gave a lecture at the Association of American Universities on "Incentives and Barriers to University/Industry Cooperation." He is on the American Institute of Chemical Engineers (AIChE) Steering Committee for Dynamic Objectives and the China Relations Committee. He is chairman for the Seventh International Symposium for Chemical Reaction Engineering to be held in Boston in 1982. He was elected Fellow of the American Association for the Advancement of Sciences. He will start a new activity as editor-in-chief of *Advances in Chemical Engineering*, a publication of Academic Press. His new editorial duties include memberships on editorial boards of *Industrial and Chemical Engineering*, *Process Design and Development*, and *Interactional Chemical Engineering*. He continues to be an editor of the Chemical Engineering series of books for McGraw-Hill Book Company, as well as on the editorial boards of *Chemical Technology* and *Chemical Engineering Communications*. He continues to serve on the visiting committee of the department of chemical engineering at the Georgia Institute of Technology. He gave the Phillips Lecture at Oklahoma State University on the "Rejuvenation of Chemical Engineering," and he gave seminars at University of Massachusetts at Amherst and at Worcester Polytechnic Institute.

Professor Robert C. Armstrong gave invited lectures at the University of Delaware and at the MIT-Industrial Liaison Office (ILO) Symposium on Polymer Processing. He presented papers at the Society of Rheology meeting in Boston, the annual meeting of the AIChE in San Francisco, and at the Industrial & Engineering Chemistry (I&EC) winter symposium on Applications of Molecular Models in Pittsburgh. He taught short courses on Polymer Fluid Mechanics for the Society of Rheology and the AIChE.

Professor Raymond F. Baddour gave lectures on "The Outlook for Petrochemical Feedstocks," at the MIT-Industrial Liaison Program (ILP) Japan Seminar in Tokyo and on "Future Prospects for Petrochemical Feedstocks" at the Korean Institute of Science and Technology in Seoul. He was a member of the US National Committee and a session chairman at the Tenth World Petroleum Congress held in Bucharest, Rumania. He was co-chairman of the symposium on "Priority Pollutants" at the AIChE 87th national meeting in Boston. He toured the Korean chemical industries in service as a consultant to the Center for Policy Alternatives on the project, "Strategies and Courses of Action for Technology Development in the Republic of Korea." Professor Baddour also served on the Center for Advanced Engineering Studies Video Publishing Advisory Committee, and on the National Medal of Science subcommittee of the AIChE. He was regional representative to Chemical Engineering Education, and a member of the Education Policy Advisory Committee of the Boston Museum of Science.

Professor János M. Beér attended meetings of the International Flame Research Foundation at Ijmuiden (Holland) and Pisa (Italy) as the Foundation's Superintendent of Research, and Chairman of the Program Executive Committee. As a member of the Science Advisory Council of the Italian National Research Council, he took part in their meeting at the University of Naples. He gave invited lectures at an international conference on fluidized combustion in Brazil and at a workshop on fluidization research needs organized by the National Science Foundation.

Dr. Samuel W. Bodman, lecturer, together with Professor Baddour, taught a new graduate level subject entitled Commercial Development of New Technology.

Professor Robert A. Brown was DuPont Assistant Professor of Chemical Engineering, and received the Outstanding Faculty Award for teaching and research given by the Graduate Student Committee of the Department of Chemical Engineering. He gave invited lectures at the Monsanto Company, Eastman Kodak Company, and at the National Engineering Foundation conference on "New Methods in Nonlinear Dynamics."

Professor Robert E. Cohen was promoted to associate professor with tenure. He spent two months at Sandia Laboratories in Albuquerque, New Mexico on the "Faculty-in-Residence Program" doing collaborative research with Sandia researchers in the area of physical aging of glassy polymers. He delivered a series of lectures on his MIT research while there. He served as local arrangements chairman for the 50th jubilee meeting of the Society of Rheology, held in Boston. He was elected to membership of the Internal Advisory Committee of the MIT Center for Materials Science and Engineering (CMSE). Professor Cohen was also organizer and coordinator of the MIT Polymer Seminar Series, and co-editor of the annual report, "Polymer Research at MIT." He was a speaker at the ILP-CMSE Materials Open House Seminar held at MIT.

Professor Clark K. Colton received the 1980 Curtis W. McGraw Research Award of American Society for Engineering Education, for his accomplishments in advancing scientific understanding of basic phenomena and in influencing practical applications in biomedical and biochemical engineering. He presented invited lectures at Cornell University, Virginia Polytechnic Institute and State University, and the Gordon Research Conference on Synthetic Membranes. He serves on the editorial board of the *Journal of Bioengineering* and he is associate editor of American Society for Artificial Internal Organs Journal. He is director of the Food, Pharmaceutical, and Bioengineering Division of AIChE. He also serves as consultant to the Dialysis Devices Subcommittee of the Panel on Review of Gastroenterological and Urological Devices of the Food and Drug Administration.

Professor William M. Deen was promoted to associate professor. He gave seminars on transport phenomena in the kidney at Carnegie-Mellon University and at Tufts University, and a research paper on this topic at the 72nd annual meeting of the AIChE in San Francisco. Seminars on hindered transport of solutes in fine pores were given at the University of Pennsylvania and at the IBM Watson Research Center. Professor Deen received an award from the graduate students in the Department for outstanding teaching and research.

Professor Lawrence B. Evans was awarded the Tenth Annual Donald L. Katz Lectureship in Chemical Engineering at the University of Michigan. The award was in recognition of Professor Evans' work in computer-aided design of chemical processes.

Professor Christos Georgakis was awarded a Camille and Henry Dreyfus Foundation Teachers Scholar Grant in recognition of his innovative research in the area of process dynamics and control. He was also the coordinator of the Departmental Seminar Series.

Professor Jack B. Howard, Executive Officer of the Department, presented lectures on coal pyrolysis and hydroxyrolysis at the University of Arizona, University of Kentucky, and Amoco Chemical Co., and he presented a paper on this subject at the American Chemical Society (ACS) national meeting in Washington, D.C. He gave seminars at General Motors Research Laboratories on soot formation in flames and at Domtar Inc. Research Centre in Montreal on coal conversion technology. He was co-chairman of the ILP Symposium "Coal Pyrolysis and Gasification," and presented a paper, "Basic Studies of Coal Pyrolysis and Hydroxyrolysis." He is a member of the National Research Council Panel on Energy Programs of the National Bureau of Standards. He is a member of the Program Subcommittee of the Combustion Institute and the Editorial Advisory Board of *Combustion and Flame*. He served on the Basic Coal Science Advisory Committee of the

Gas Research Institute, and he heads a review panel of the Institute for Mining and Minerals Research of the University of Kentucky. Professor Howard is also a member of the steering committee of the 1980 General Motors Research Symposium on "Particulate Carbon Formation during Combustion."

Professor John P. Longwell received the 1979 American Institute of Chemical Engineers award for chemical engineering practice. He was co-chairman of the ILP symposium "Coal Pyrolysis and Gasification," and presented a paper, "Fluidized Bed Pyrolysis of Coal in the Presence of Dolomite." A paper on "Particulates Formation" was presented at the ILP Symposium "Automotive Engine Research." He gave a seminar, "The Future of Aviation Gas Turbine Fuels," at General Electric Co., and a paper, "Combustion of Synthetic Fuels," at a meeting of the Eastern Section of the Combustion Institute. Professor Longwell served as chairman of the National Research Council's Committee on Advanced Energy Storage Systems and as a member of the NASA Propulsion Advisory Committee. He also served as chairman of the working group on Combustion, Thermal, and Fluid Sciences with the responsibility of preparing a program guidance report for the proposed Cooperative (government and industry) Automotive Research Program.

Professor Edward W. Merrill gave invited lectures to the chemical engineering departments of Tufts University, Cornell University, and Purdue University on aspects of polymer materials for biomedical uses. On the occasion of the Purdue lecture, he received a citation naming the 39 doctoral students whose theses he directed during his 30 years on the MIT faculty. Presented by one of the 39, Professor N.A. Peppas of Purdue, the citation took the form of an "educational family tree" which showed former doctoral students who themselves are now professors, and their doctoral students, as well as Professor Merrill's own doctoral thesis director, MIT Professor Herman P. Meissner. Professor Merrill also addressed the Alumni Officers Conference at MIT. He was a member of the program committee of the Society of Rheology annual meeting in Boston and was organizer of the two-day symposium on Biorheology. At this meeting he presented a paper on polymers in drag reduction. He is also on the program committee for the August 1980 meeting at MIT of the International Committee on Thrombosis and Hemostasis.

Dr. C. Michael Mohr, senior lecturer, continued work with members of the Center for Advanced Engineering Studies on the development of a series of technical modules on energy conservation. This series, designed for use by individual engineers in industry, is currently going into publication and some of the material is being adopted for computer-aided instruction on a nationwide commercial computer network.

Professor Frederick A. Putnam held the Joseph R. Mares Career Development Chair and was promoted to associate professor. He served on the winter symposium program committee of the American Chemical Society Industrial & Engineering Chemistry Division, and on the colloid and surface science symposium committee of the American Chemical Society Colloid and Surface Chemistry Division. He was elected secretary of the Gordon Conference on Chemistry at Interfaces. Professor Putnam served on a meeting program committee of the AIChE, and he served on the faculty committee which advised the MIT Corporation on the selection of the next President of MIT.

Professor Robert C. Reid was elected to the National Academy of Engineering and served as a member of the special committee of the Academy to evaluate the safety hazards involved in importing liquified natural gas into the United States. He also served as chairman of the advisory committee for the Division of Energy and Environment of the Brookhaven National Laboratory. Professor Reid was also a member of the visiting committee of the Chemical Engineering Department of Princeton University and was elected to the editorial board of the *Journal of Chemical Engineering Data*. He was awarded the Olaf A. Hougen Professor of Chemical Engineering at the University of Wisconsin for the 1980-81 academic year.

William C. Rousseau, visiting senior lecturer, continued valuable service to the Department, especially to the Practice School.

Professor Adel F. Sarofim served on the task force identifying research needs in the areas of conventional and advanced coal technologies, reporting to the Federal Interagency Committee on the Health and Environmental Effects of Energy Technologies. He also served on the technical panel for the Low-NO_x Burner Development Program of the EPA, and on the editorial advisory boards of *Progress in Energy and Combustion Science* and *Combustion Science and Technology*.

Professor Charles N. Satterfield's fifth book *Heterogeneous Catalysis in Practice* was published by McGraw-Hill and has received enthusiastic reviews. Although it was written largely for professional use, many faculty members in the US and abroad are already planning to adopt it as a classroom text. Professor Satterfield presented for the second time a course on heterogeneous catalysis for the Exxon Research and Engineering Co., as a part of their in-house technical education program. He also gave invited lectures at the Technical University of Berlin, the Royal Dutch Shell laboratories in Amsterdam, Akzo Chemie in Amsterdam, and Carnegie-Mellon University. He presented research papers at the Sixth International Symposium on Chemical Reaction Engineering, Nice, France, and at the annual meeting of the AIChE. He also developed and presented a new course at MIT on multi-phase chemical reactors.

Professor Selim M. Senkan returned to Cambridge after completing a two-year assignment as director of the School of Chemical Engineering Practice at Oak Ridge, Tennessee.

Professor Kenneth A. Smith delivered papers at several technical meetings and presented an invited seminar at Tufts University. He was a member of the editorial board of the AIChE Journal and of the visiting committee for the chemical engineering department at Lehigh University. In July of 1979, he was one of a delegation of nine MIT faculty members who visited the People's Republic of China at the invitation of Tsinghua University in Peking. Effective July 1, 1980, he will become Associate Provost of the Institute.

Professor Costas G. Vayenas held the DuPont Assistant Professorship of Chemical Engineering. He gave invited lectures at Celanese Co., the General Motors Corp., and the New England Catalytic Society meeting.

Professor J. Edward Vivian served as chairman of the general arrangements committee for the 87th national meeting of the AIChE held in Boston. He resigned as Executive Officer of the Department in September 1979 to devote full-time to teaching and to the office of director of the School of Chemical Engineering Practice.

Visiting scholars in the Department during the year included Dr. Karl-Heinz Reichert of the Technical University of Berlin, West Germany; Dr. W. John Thomas, University of Bath, United Kingdom; Dr. Ralph A. Troupe of Northeastern University; and, from the People's Republic of China, Yougi Yang of the Central Institute in Peking and Wei-Kang Yuan of the Shanghai Institute of Chemical Technology.

Awards

The Department gave the following awards to six Chemical Engineering students at its annual awards presentation in May.

The Robert T. Haslam Cup, awarded annually to a senior for outstanding professional promise in chemical engineering, was given to Ronald J. Weigel.

The Roger de Friez Hunneman Prize, provided by a fund established in 1927 by William Hunneman in honor of his son, and awarded for outstanding originality in chemical engineering, was given to senior Scott H. Kubowicz.

The American Institute of Chemists Award, offered to a senior in chemistry and/or chemical engineering who displays outstanding promise, was awarded to Diana M. Altrichter.

The American Institute of Chemical Engineers annual scholarship award was given to junior John G. Tsikoyiannis.

The Chevron Undergraduate Scholarship, presented for outstanding academic performance in the Department and for high professional promise as a chemical engineer, was awarded to Theresa A. Weston.

The Chemical Engineering Special Service Award, presented in appreciation of unselfish contributions to the success of Department activities, was given to graduate student John E. Nenniger.

RESEARCH

The research volume of the Department was approximately \$1.8 million compared to \$1.7 million in 1978-79, and \$1.7 million in 1977-78. When interdisciplinary research activity for which Department faculty are responsible is included, the volume was approximately \$6 million compared to \$5.4 million in 1978-79 and \$4.1 million in 1977-78. The Department's research extended over a wide range of activity with energy and fuel projects, reactor performance studies, polymer studies, and biochemical and biomedical research accounting for the major portion.

A 10-year agreement for support of combustion research at MIT has been reached with Exxon Research and Engineering, providing an exciting opportunity for university/industry interaction. Professors Longwell and Sarofim are the principal investigators of this \$7 million project. A novel feature of the agreement is the allocation of 20 percent of the research funds for exploratory research. This new mode of industry/university cooperation has attracted a great deal of attention throughout the country.

Professor Armstrong supervised research on fundamentals on non-Newtonian fluid mechanics and applications to polymer processing. Concentration of effort in this research has fallen in two general areas: rheological properties of filled polymers, with particular emphasis on constitutive modeling and structure/property relationships, and numerical simulation of viscoelastic fluid flows.

Professor Baddour initiated research on microbial extraction and modification of oil shale kerogen. This program is directed towards an attempt to release oil from the kerogen, and remove the organic sulfur and nitrogen, in one microbial process. In another project, the technology and economics of gasifying wood and producing methanol from the resulting synthesis gas were examined. Professors Baddour and Cohen continued their research on flourination of polymers in a cold plasma. Professor Baddour was also active in research on the synthesis of hydrogen sulfide from coal, sulfur, and steam in a DC arc, and on a fermentation system of microorganisms growing on globular microcarriers in submerged cultures. In the latter work, the production of penicillin by the organism *penicillium chrysogenum*, using various solid microcarriers, is being studied.

The Combustion Research Facility under the supervision of Professor Beér was fully operated with gaseous and liquid fuels, and research was conducted on several projects related to the reduction of polycyclic aromatic hydrocarbon and nitrogen oxides emission from turbulent flames of liquid petroleum and coal-derived fuels, and on advanced combustion diagnostics for turbulent flame studies. This research facility provides unique opportunities for the application of results of basic studies to industrial combustion systems, and for the rigorous experimental testing and further development of mathematical models of the combustion, heat transfer, and pollutant formation processes in flames. Professor Beér, in collaboration with Professor Sarofim, carried out research on the modeling of pollutant emission from fluidized bed combustors. The model development was guided by laboratory-scale critical experiments, and the predicted data were tested using the 2'x2' fluidized Combustion Research Facility.

Professor Brown continued research into the fundamentals of the growth of single-crystal metals from the melt. Efforts focused on numerical simulation of the heat, mass, and momentum transfer important to the floating zone process, and were directed toward the version of that process to be tested aboard NASA's Space Shuttle. Professor Brown initiated studies of methods for producing the hollow spherical shells needed as fuel targets for inertial confinement fusion reactors. Another study supervised by Professor Brown in collaboration with Professor Armstrong dealt with new methods for the numerical simulation of non-Newtonian flows.

Research by Professor Cohen in the area of block copolymers and polymer blends led to the issuing of a patent, "Homogeneous Elastomer Blends," by R. E. Cohen and A. R. Ramos, assigned to MIT. His joint research with Professor Baddour in the area of cold plasmas led to a process by which the outer surface layers (~100 Å) of various polymers can be converted to a perfluorinated material with desirable properties similar to those of the commercial product "Teflon" (polytetrafluoroethylene). Patent applications have been filed. A new research initiative in collaboration with Dr. Charles Berney of the Department of Nuclear Engineering, involves small angle neutron scattering experiments at the new National Small Angle Scattering Facility at the Oak Ridge

National Laboratory. Interfaces in heterogeneous block copolymers will be studied.

Professor Colton carried out research related to development of a hybrid artificial pancreas in collaboration with Dr. William Chick of the Joslin Research Laboratory, Harvard Medical School. The device consists of pancreatic beta cells cultured on the exterior surface of semipermeable tubular membranes. Experimental and theoretical investigations were initiated to study the insulin secretory dynamics of the device in response to a step change in glucose concentration. Professor Colton also collaborated with Professor Smith in research on arteriosclerosis (see below).

Professor Deen continued research dealing with transport processes in the kidney, leading to the first quantitative models of electrostatic effects in capillary ultrafiltration and of the handling of bicarbonate by the kidney. Research on hindered transport in synthetic membranes led to new results concerning the effects of molecular configuration on diffusion in fine pores, and the strength of electrostatic double layer interactions between permeating solutes and pore walls. A new project was undertaken in collaboration with Professor Steven Tannenbaum of the Department of Nutrition and Food Science to study the handling of nitrate and its metabolites in the body.

Development of ASPEN (Advanced System for Process Engineering) was essentially completed during the past year and the project, directed by Professor Evans, began a two-year testing and technology transfer phase in partnership with industry. ASPEN is a computer-based process simulator and economic evaluation system that simulates the flowsheet of a proposed or operating chemical plant and provides preliminary estimates of capital and operating cost. During the past year about 13 full-time staff members, many on loan or on leave from industry and other universities, participated with about 30 students on the project. Over 45 companies are participating in the testing program. Public release of ASPEN is scheduled in 1981.

Professor Evans and Professor Daniel I.C. Wang of the Department of Nutrition and Food Science continued their research on the dynamics and control of industrial fermentation systems. They are presently working to exploit a new sensor, called the filter probe, that can monitor cell biomass concentration and morphology during the fermentation. The goal is to develop improved methods for control and optimization of penicillin fermentation.

Professor Evans with Joseph Boston and Herbert Britt of the ASPEN Project developed a new algorithm for optimization of process flowsheets, called the simultaneous modular algorithm. The new approach resulted in an order of magnitude improvement in computational efficiency for solving large problems. These workers also continued their work on modeling and simulation of processes involving electrolytes. A new approach was developed to correlate the activity coefficients of systems involving electrolytes and mixed solvents. The new correlation was able to handle systems encountered in acid gas scrubbing processes that had previously been described only with the use of specialized empirical equations.

Professor Georgakis conducted research in the control of fluidized bed catalytic crackers where a new control policy was developed. He also continued to work in the control of gas-absorption-stripping system as well as in the modeling of fluidized bed combustors. In the last topic, the developed model was used to calculate extinction and ignition characteristics that are very important in the operation of fluidized beds combustors. He also initiated a new project on fluidized bed dryers in an effort to develop more efficient control policies which could conserve energy in such important operations.

Professors Howard and Longwell continued research on the mechanism of soot formation, with emphasis on the role of aromatic fuel components which are expected to be of increasing importance with the use of coal and coal-derived liquid fuels. These workers, in collaboration with Professor Sarofim, Dr. William A. Peters, and Dr. Gilles Prado of the Energy Laboratory, studied the formation of soot and polycyclic aromatic compounds in laboratory flames under ranges of conditions relevant to practical combustion equipment. Professor Howard and Dr. Peters continued basic studies of coal pyrolysis and hydrolyrolysis, with a focus on the effects of inherent coal minerals and process conditions.

Professor Longwell, in collaboration with Dr. Peters, extended his previous research on the effect of calcium oxide on pyrolysis of coal to pyrolysis of lignite and wood. He collaborated with Dr. Prado in extending the study of polycyclic aromatic compounds and soot formation to tests in commercial combustion equipment. In collaboration with Professor Howard and Dr. Peters,

Professor Longwell is studying the kinetics of cellulose, lignite, and wood pyrolysis. With Professor Sarofim, he initiated the long-term research program in the field of combustion under the new Exxon-MIT research agreement mentioned above.

Professor Merrill and his associates, Drs. A.K. Dincer and V. Sa da Costa, continued studies on polymers for medical applications and as model networks. As a contribution to the science of rubber elasticity, end-linkable linear silicone molecules (elastic chain molecules) were synthesized and then connected to a different silicone molecule (junction molecules) each leaving end-connecting sites for the chains that ranged from 3 for one type to 80 for another. They then formed silicone rubber networks in which the functionalities of the junction and the chain molecular weights were varied over a wide range, exceeding any previously reported work. In collaboration with Dr. E.W. Salzman of Harvard Medical School and Beth Israel Hospital, Dr. David F. Waugh, of MIT's Biology Department, Dr. Robert Rosenberg, of Sydney Farber Cancer Center, and their groups, made significant progress on two classes of biomaterials potentially useful for contact with blood. A new type of heparin having strong affinity for antithrombin (from Dr. Rosenberg's laboratory) was covalently bound to synthetic polymer surfaces by a four-step procedure, and was found to act as a catalyst for the coupling of antithrombin to thrombin as it does in free solution. Furthermore, the effect is several fold greater than obtainable with conventional heparin used clinically. Tested *in vitro*, this heparinized material is relatively bland toward platelets as compared to other heparinized materials. Polyurethanes, based on polyethylene oxide as the chain, were developed and were shown to be significantly less activating toward blood platelets than conventional biomedical polyurethanes. In all, 45 different polyurethanes were synthesized and studied. The evidence points to polyethylene oxide, (in network form rather than as linear single molecules) as being potentially a bland, hydrophilic, blood compatible elastomer.

In other work, Professor Merrill studied the kinetics of electron radiation degradation of PCB (chlorinated biphenyls) in water. He and M. Phillips of The Society for Preservation of New England Antiquities, Boston, supervised research in which precipitation polymerization of methylmethacrylate in crumbling plaster was shown to be a promising method of restoration of mechanical strength.

Professor Michael Modell continued to study the unusual and relatively unexplored properties of water in the range of its critical conditions (374°C, 220 atm) when it becomes an excellent solvent for organic compounds, such as benzene and naphthalene. Applications of potentially broad significance being explored are the reforming of organics as a potential biomass-to-fuel and waste treatment process, and the liquefaction and gasification of coal. A third application is the technical feasibility of using supercritical water to decontaminate dredge spoils.

Professor Reid continued his study of supercritical fluid extraction using carbon dioxide and ethylene as solvent fluids. Equilibrium solubilities were determined for a number of pure solids and solid mixtures.

Professors Manning and Reid developed what appear to be superior catalysts for the Bosch process reaction to reduce metabolic carbon dioxide to carbon in long-range space flights. The catalysts, cobalt and nickel, were found to be much less sensitive to water vapor formed in the reaction.

Professor Sarofim collaborated with Professor Longwell in the initiation of the above mentioned long-term research interaction with Exxon Research and Engineering. The areas of investigation include soot formation, heterogeneous reactions of fuel nitrogen compounds, char gasification kinetics at combustion temperatures, and the capture of sulfur by mineral constituents in coal during combustion.

Professors Beér, Georgakis, and Sarofim have continued their contributions to the development for the Department of Energy (DOE) of an integrated model of a fluidized bed combustor. The model considers reactions occurring both in the bed and freeboard and includes simulations of the carbon loading, CO and NO_x emissions, carbon combustion efficiency, and stability limits.

Professors Sarofim and Longwell have extended their studies on the control of NO_x emission by fuel rich combustion by examining the interaction of hydrocarbons and nitrogen oxide and developing kinetic codes to simulate the profiles of stable species under well-controlled conditions in a flat flame burner burning nitrogen-doped ethylene.

Professors Beeř and Sarofim have examined the pyrolysis of nitrogen from coal and heavy fuel oils burned or pyrolyzed under well-controlled conditions in a laminar flow furnace. These studies have been complemented with studies on the reduction of NO by char, its enhancement by CO, and inhibition by O₂ and H₂O. These studies provide kinetic inputs to the models of NO formation and destruction in both fluidized bed and pulverized coal combustors.

The effects of combustion temperature and time on the internal structure of char and the amounts of soot produced during the entrained pyrolysis of coal are being studied by Professors Howard and Sarofim. These data are of interest in the modeling of pulverized coal combustors.

An interdisciplinary team consisting of Drs. Amdur, Elliott, and Sarofim is examining the health effects of sulfur oxides and inorganic particulate. The effort in chemical engineering is on the characterization of the size and chemical composition of the submicron aerosol produced by the vaporization, condensation, and agglomeration of volatile mineral components of coal.

Professors Longwell, Howard, and Sarofim are examining the composition of polycyclic, potentially carcinogenic, compounds produced either as primary pyrolysis products of coals and alternative fuels or by pyrosynthesis reactions in diffusion flames prevalent in many practical combustors.

Studies of catalytic hydrodenitrogenation (HDN) on a commercial NiMo/Al₂O₃ catalyst using quinoline as a model compound and with various reaction intermediates, continued under the supervision of Professor Satterfield. Recent results showed that a principal limitation to the HDN rate under industrial processing conditions is the strong adsorption of secondary amines formed as reaction intermediates, and not the rate of reaction of anilines formed as intermediates, as had been previously believed. Hydrogen sulfide, which will always be present in industrial processing, slightly inhibits the hydrogenation steps in the overall reaction but markedly accelerates the hydrogenolysis steps. The net effect is acceleration of the overall HDN reaction under many conditions. These conclusions have considerable significance for the design of improved catalysts and for modeling hydrodenitrogenation reactors.

Studies of the Fischer-Tropsch reaction in a mechanically agitated liquid-phase slurry reactor are revealing the marked effects of mass transfer limitations on product selectivity. This is of especial importance when the Fischer-Tropsch reaction is to be directed toward production of specific chemical compounds such as ethylene and other olefins.

Professor Senkan conducted research examining the mechanism of freezing damage in living systems, using liposomes as model systems. He supervised research in which the practical aspects of heat exchanger/reactor concepts are investigated. He also started a new research program examining the combustion characteristics of halogenated hydrocarbons to aid the development of hazardous chemical waste incinerators.

Professors Smith and Colton, in collaboration with Professor Robert S. Lees of the Arteriosclerosis Center and Professor M.B. Stemerman of the Beth Israel Hospital, continued research related to factors which may cause arteriosclerosis. By means of a serial sectioning technique, they had earlier shown that the single layer of endothelial cells normally offers the dominant resistance to the transport of proteins within the arterial wall, but rates increase 10-fold if this single layer of cells is damaged. This discovery motivated a search for methodologies capable of providing much greater spatial resolution, and the major accomplishment of the current year has been development of a novel quantitative autoradiographic technique which satisfies that requirement.

Professors Smith and Reid, and Professor Preetinder Virk supervised research directed at safety problems which arise in the context of liquefied natural gas (LNG) and liquefied petroleum gas (LPG) handling operations: the rate at which they boil and spread when spilled upon water, land, or a variety of insulating materials; the response of stored liquid to a change in atmospheric pressure; and the phenomenon of roll-over due to composition-induced density gradients in storage tanks. Flameless vapor explosions, which are associated with spontaneous nucleation in superheated liquids, were also under investigation.

Professor Costas Vayenas supervised research on a new fuel cell concept in which ammonia is electro-oxidized to nitric acid with simultaneous production of electrical energy. He also supervised a project on the use of solid electrolytes to study the mechanism of partial catalytic oxidations and to enhance electrocatalytically their selectivity to valuable products.

Reaction pathways involved in coal and wood processing are being explored in three areas by Professor Virk. First, a novel pericyclic mechanism has been proposed for hydrogen transfer during coal liquefaction, and experiments using a variety of model donors and acceptors are in progress to test this hypothesis. Second, thermal reactions of lignin precursors are being investigated with a view to discerning mechanisms for gas release and the associated formation of substituted phenols and char. Finally, perturbational molecular orbital (PMO) calculations, using extended Huckel theory in conjunction with Fukui's frontier orbital analyses, are being conducted to explore the dominant interactions responsible for selected pericyclic reactions; these will serve as a theoretical framework for experimental results.

Professor Virk is also studying the mechanism of drag reduction by macromolecular solutions in turbulent pipe flow using collapsed and extended polyelectrolytes. The object is to discern whether or not all additives affect the flow in an equivalent manner, that is, results in quantitatively identical mean and turbulent flow structure at a given gross drag reduction.

Professor Wei supervised research on the catalytic hydrodemetallation process for the removal of metallic components from residual fuel oils, using autoclave and continuous high pressure fixed-bed reactor techniques. He also continued in the mathematical modeling of coal gasification reactors, both for simulation of existing plant data and for predicting performance in new design and operations. The simulation has been very successful in moving-bed reactors, such as the Lurgi dry ash and slagging reactors; it is being extended to entrained bed reactors, such as the Texaco and Bi-Gas reactors. He started research on the conversion of methanol to the petrochemical feedstocks olefins and aromatics through the zeolite catalysts AXM-5. He has also begun research on the optimal size of a chemical plant under uncertainties of market demand, price, raw material availability, new technologies, and governmental interventions.

JAMES WEI

Department of Civil Engineering

The Department of Civil Engineering entered the decade of the 1980s with many reasons for optimism about its future. Graduate enrollment and research support are at all-time highs; demand for graduates at every degree level is intense; faculty members occupy a broad spectrum of leadership positions in professional societies and government; and the challenges of providing energy, food, shelter, transport, and other basic human needs assure that civil engineers will continue to occupy central roles in our technological society. However, two disturbing factors, which were dimly hinted at in recent years, became clearly defined problems during the past year. The first of these problems is a declining undergraduate enrollment at a time when many other engineering departments at MIT and elsewhere are experiencing unprecedented growth and enrollment levels. The second problem is a national decline of interest in graduate education by US students, especially at the Ph.D. level.

The drop in undergraduate enrollment was first observed in the fall of 1977, and at that time we forecast a continued small decline over the next few years. However, it became apparent early in the 1978-79 academic year that the declining interest in civil engineering by MIT undergraduates was more pronounced than had been anticipated. Two years ago we began to deal with this problem by increasing our efforts to bring civil engineering to the attention of first-year students and by initiating a major review of our undergraduate curriculum. The latter effort resulted in adoption of a new undergraduate curriculum which is scheduled for implementation in the fall of 1980. We hope to better convey to our students the exciting challenges and careers to be found in the field of civil engineering, and to prepare them for positions of leadership.

The national decline of interest in graduate education has recently been recognized by engineering educators. It has been especially felt in the field of civil engineering and is present at both the Masters and Ph.D. degree levels. The declining interest in graduate education is having two direct impacts on the Department. First, there is increased pressure to increase the percentage of foreign graduate students beyond traditionally accepted levels. As the number of US graduate

school applicants has dropped and the number of well-qualified foreign applicants has increased, we are inevitably forced to be less selective among US candidates or to increase the foreign student percentages. Second, as the pool of US citizen/Ph.D. students from which to select new faculty members decreases, we find the percentage of foreign-born faculty members rapidly increasing.

The fact that the foreign student and faculty percentages are increasing is not itself a source of concern. Their presence in our programs is essential in maintaining the highest levels of quality, and reflects our continued role as an international force in civil engineering education and research. However, as a symbol of not fully understanding pressures on US students and our failure to convey the benefits of graduate education, it is a source of concern.

It is well to note, however, that the Department continues to play a significant role in foreign countries and that much of the research and professional activities of the faculty is international in scope. This is certainly not surprising when one considers the vital role that civil engineering plays in the development of every country's infrastructure.

Undergraduate Program

The declining undergraduate enrollment noted earlier is made more specific by the data presented in the table below. The first year of the table, 1976, was our post-World War II high, a peak that was reached after a relatively gradual rise over a 15-year period.

	<u>Undergraduate Enrollment</u>			
	<u>1976-77</u>	<u>1977-78</u>	<u>1978-79</u>	<u>1979-80</u>
Sophomore	52	38	31	32
Junior	67	67	53	40
Senior	<u>57</u>	<u>61</u>	<u>69</u>	<u>68</u>
Total	176	166	153	140

Even though the total enrollment of 140 undergraduates during the past year is a higher figure than was experienced in any year for the period 1960 through 1974, we are concerned that the gains of recent years may be quickly eroded if positive actions are not taken. Our concern is further heightened by preliminary indications of a further drop in our sophomore enrollment to about 20 students in the fall of 1980.

A further source of concern is the apparent paradox of our declining enrollment while the rest of the School of Engineering is at an all-time high. However, enrollment trends of the Department of Civil Engineering have typically been out of phase with the rest of the School reflecting perhaps a perception of the Department's tighter ties to public works and infrastructure planning issues, rather than the high science and technological change issues so strongly identified with other engineering departments. It does appear that the Department must do a better job of conveying its concern for the hard technology of civil engineering as well as the planning/policy aspects of the field, if, in the short run, it is to compete successfully for a reasonable share of the available students.

The new undergraduate program which was described in last year's report was officially approved by MIT's Committee on Curricula and will be offered for the first time to the incoming sophomore class this fall. The sophomore core portion of the program has undergone intensive development during the past year under the direction of our Undergraduate Academic Officer, Professor Robert V. Whitman. The entire new program was developed under his direction. The new sophomore core subjects have been developed and will be taught initially by four of our most outstanding teachers, viz.:

Civil Engineering Systems Analysis I	-- Associate Professor H. Max Irvine
Civil Engineering Systems Analysis II	-- Associate Professor Keith D. Stolzenbach
Behavior of Physical Systems I	-- Associate Professor Steven R. Lerman
Behavior of Physical Systems II	-- Professor David H. Marks

The integration of these subjects into a unified sophomore experience will be led by Professor Whitman.

Each of the three departmental divisions has also designed a new structured program for third- and fourth-year students in the areas of transportation, constructed facilities, and water resources and environmental engineering. Students will be required to complete at least one of these three upperclass options.

A major feature of the new curriculum is the degree of structure that has been returned to our undergraduate program. It is hoped that this structure, especially the common sophomore experience and the more tightly designed upperclass options, will provide incoming students with a greater sense of departmental unity and a more coherent understanding of the many elements that make up the practice of civil engineering. At the same time we feel that sufficient flexibility has been retained to accommodate a broad range of interests.

Graduate Program

Graduate enrollment figures for recent years are presented in the following table.

	<u>Graduate Enrollment</u>			
	<u>1976-77</u>	<u>1977-78</u>	<u>1978-79</u>	<u>1979-80</u>
Regular	202	220	243	252
Special	16	18	23	20
Total	<u>218</u>	<u>238</u>	<u>266</u>	<u>272</u>

The enrollment for the past year is the highest in our history and reflects a steady growth that has continued throughout the post-World War II period. Graduate enrollment is constrained primarily by the size of the faculty and the availability of research support. Our graduate enrollment has increased more than 40 percent during the past decade -- a period in which there has been no increase in the number of faculty members. This large growth imbalance has been achieved through real growth in that period of our research program and an attendant increase in full-time research staff.

Quantitative evidence of the declining interest in graduate education among US students is provided by the following data.

	<u>US Citizens</u>		<u>Foreign Applicants</u>	
	<u>1975</u>	<u>1979</u>	<u>1975</u>	<u>1979</u>
Number of Applications	211	140	178	263
Number Offered Admission	127	107	37	73
Number of Acceptances	67	51	24	55

These indicate that the number of US applications has declined in four years by about one-third, and the number of new graduate students actually choosing to come to MIT decreased by about one-quarter. At the same time, applications from foreign students increased by nearly 50 percent, the number admitted more than doubled, and, for the first time, the number of new foreign graduate students exceeded those from the US. Since relatively fewer US students remain for the doctorate, these figures are even more heavily weighted toward foreign students in the doctoral program. The implications for faculty staffing in the US are evident and have clearly been observed in our own recent faculty searches.

There has been much speculation as to the causes of the decline of US students' interest in graduate education. Reasons posited include the influence of high starting salaries for recent

S.B. degree recipients, uncertainty over the future state of the economy, the impact of large financial debt by undergraduates, and a possible increase in the attractiveness of graduate degrees in other fields, especially business and law. Some have even proposed that today's figures simply represent a return to a more normal situation that was temporarily distorted by the draft and Vietnam War era. At present, we simply do not understand the causes of current trends, but we are challenged to present our case for graduate study more effectively to potential US students.

Because of the emphasis on development of our new undergraduate curriculum there has been less than the normal amount of new graduate subject development during the past year. However, several new subjects deserve special mention. Professors Oral Buyukozturk, Jerome J. Connor, and Erik H. Vanmarcke, along with two faculty members in the Department of Ocean Engineering, offered for the first time 1.533J Analysis and Design of Offshore Structures. Professor C. Allin Cornell introduced a new subject, 1.552 Structural Loads, based on his research in recent years on this topic. Professor Ann F. Friedlaender's introduction of the subject 1.184J Economics of Project Evaluation represents one of several steps currently being taken to place several economics and project evaluation subjects of interest to our Department on a more structured basis. Professor Donald R.F. Harleman's new version of 1.85 Introduction to Water and Waste Water Treatment Engineering represents a step toward renewed emphasis on treatment issues in our environmental engineering program. In a related development, Professor Harold F. Hemond introduced the subject 1.75 Limnology and Wetland Ecology. Professor Marie-Elisabeth Paté presented a new subject, 1.482 Engineering Risk-Benefit Analysis, which has been adopted by the School of Engineering as a School-Wide Elective. Professors Yosef Sheffi and J.K. Hedrick of the Mechanical Engineering Department, helped to renew our concern for the technology of transportation with their new offering, 1.290J Transportation Performance and Technology.

The new master's degree program in transportation offered by the Center for Transportation Studies began operation in the fall of 1979, and, as described in last year's report, resulted in the creation of several new departmental subjects.

RESEARCH

The Department's faculty were engaged in an unusually broad spectrum of research activities during the past year. Rather than attempting to summarize all of these, this year's report will concentrate on projects of great importance in two areas, namely energy and infrastructure development in foreign countries. The first area is chosen because of its great importance to development in the US; the second is in recognition of the vital importance of civil engineering to international development.

In the area of energy, Professor David B. Ashley is working with the Harvard-MIT Joint Center for Urban Studies on energy efficiency in residential housing. Professor Buyukozturk's research on the thermo-mechanical analysis of refractory concrete vessels has led to new design criteria for coal gasification vessels. He also continued important work on the safety assessment of concrete nuclear structures and has demonstrated the importance of micro-cracking as a factor in the ultimate safety of these vessels.

Professor Sallie W. Chisholm has continued her work for Exxon on the possible use of lipid-rich algae as a renewable source of conventional liquid fuels. Professor Harleman's program on waste heat management has been particularly concerned during the past year with the analysis of cooling ponds and hydrothermal models. He also has participated in studies of offshore thermal energy conversion schemes and solar ponds as new energy sources. Professor Hemond's studies of the effects of acid rain on wetland ecosystems will surely become important as a possible constraint on the expansion of coal use in the US. Professor Chiang C. Mei continues to explore the theory of ocean wave energy extraction devices, with the purpose of improving their realizable efficiency.

Through the Center for Transportation Studies, Professor Daniel Roos and several colleagues have launched a major study to develop emergency transportation plans which could be invoked in the event of a significant reduction in the availability of imported oil. Under his direction the Center also has undertaken a study to explore the future of the automobile as a transport medium.

In the area of infrastructure development in foreign countries, MIT's Technology Adaptation Program is the largest single source of research. This major project, which is funded by the Agency for International Development (AID), is directed by Professor Fred Moavenzadeh and at present is concentrated on research problems in Egypt. Faculty of the Department who are involved and their research topics include:

Professor David B. Ashley	--	Housing and the Construction Industry in Egypt
Professor Mohsen M. Baligh	--	Evaluation of Paraffinic-Waxy Asphalts in Egyptian Road Construction
Professor Rafael L. Bras Professor Peter S. Eagleson	--	Stochastic Inflows of the Nile River into Lake Nasser
Professor David H. Marks	--	Water Resources in Egypt
Professor Michael Meyer Professor Nigel H.M. Wilson	--	Transportation in Cairo
Professor John L. Wilson	--	Regional Groundwater Studies

A second major international project dealing with structures for offshore oil exploration in Venezuela is sponsored by Instituto Tecnológico Venezolano Del Petróleo (INTEVEP) and is directed by Professor Jerome Connor. Other participants and research areas include, Professor Baligh (Soil Properties of Offshore Orinoco Delta Clays) and Professor Charles C. Ladd (Evaluation of Compositional and Engineering Properties of Offshore Venezuelan Soils).

Through the Center for Transportation Studies, several faculty members of the Department, including Professors Moshe Ben-Akiva, Steven Lerman, Marvin L. Manheim, and Professor Roos, have begun a cooperative program of research and education with Brazilian Enterprise for Transportation Planning (GEIPOT) on multimodal transportation.

In addition to these larger joint ventures, several individual efforts are under way. These include a study of port planning in Nigeria by Professor Paul O. Roberts and a study of the hydrothermal electric system in Spain by Professor Bras.

FACULTY

Faculty promotions included Dr. Gregory B. Baecher, and Drs. Chisholm and Irvine to associate professor.

The resignation of Professor Raymond E. Levitt was received with regret. Professor Levitt is joining the faculty at Stanford University. Professor James E. Becker reduced his commitment to half-time, in anticipation of a resignation in 1982 to enter private industry.

Searches were successfully completed for two new faculty members who will join the Department during the 1980-81 academic year. Dr. Wallace K. Melville, currently a research staff member at the Scripps Institution of Oceanography, will become an associate professor in our Water Resources and Environmental Engineering Division. Dr. Henry Irwig, currently associate professor at Case Western Reserve University, will join our Construction Engineering and Project Management Program (CEPMP) at that same level.

The Department was pleased to have had the following visiting faculty during the past year: Dr. Hans Bjornsson joined us on leave from his faculty position at the Chalmers Institute of Technology in Sweden and substituted ably in our CEPMP Program for Professor Robert G. Logcher who was on leave. Dr. Paul Kruger joined us from his position as professor of nuclear civil engineering at Stanford University. Dr. Gedaliah Shelef joined our Water Resources and Environmental Engineering Division as visiting associate professor to work on advanced waste water treatment problems. He was on leave from the Technion in Israel. Professor Hugo Perez

La Salvia was on leave from Catholic University in Venezuela to provide liaison with the INTEVEP Program.

Four members of the Department's faculty were on leave during the academic year. Professor Logcher spent a sabbatical leave working part-time with a major contractor and spending some time at Stanford University. Professor Joseph M. Sussman was also on sabbatical leave studying at the Sloan School of Management and doing research at MIT. Professors Baecher and Ole S. Madsen were on leave at the Technical Universities of Munich and Denmark respectively.

The accomplishments of the Department's faculty were acknowledged in many ways through publications, selection for committee membership, and awards. Among the most notable of these were the following:

Professor Chisholm was selected as the Doherty Associate Professor of Ocean Utilization for a two-year term.

Professor Eagleson won the prestigious Robert E. Horton Award of the American Geophysical Union (AGU) for his contributions to the field of hydrology. He was also elected president of the Hydrology Section of the AGU.

Professor Hemond was selected as a recipient of a Whitaker Health Sciences Fellowship.

Professor Irvine was chosen as an Edgerton Professor for a two-year term.

Professor Levitt's book, *Union and Open Shop Construction: Compensation, Work Practices, and Labor Markets*, which he coauthored with Clinton C. Bourdon was published by Lexington Books.

Professor Manheim's long-awaited book, *Fundamentals of Transportation Systems Analysis*, Vol. I, was published and quickly received outstanding reviews.

Professor Frank E. Perkins was elected president of the Boston Society of Civil Engineers Section of the American Society of Civil Engineers (ASCE).

Professor Vanmarcke was coauthor of a paper that was selected to receive the 1979 T.R. Higgins Lectureship Award of the American Institute for Steel Construction.

Professor Whitman received one of the highest forms of recognition among geotechnical engineers through his selection as the 1981 Terzaghi Lecturer by ASCE.

A personal note:

This is my last report as Head of the Department of Civil Engineering since I have accepted the position of Associate Provost at MIT effective July 1, 1980.

I am deeply grateful to my fellow faculty members for their support, and I hope my successor will receive the same warm and devoted support that was extended to me during my tenure as Department Head.

FRANK E. PERKINS

Department of Electrical Engineering and Computer Science

Noteworthy educational developments in the Department during the past year took three directions: acquisition, installation, and operation of the new Departmental computer facility; development of a new graduate-level set of "core" subjects for computer science; and selection of personnel and program for the Bernard Marshall Gordon Chair of Engineering Innovation and Practice.

The Departmental computer facility comprises at present a DEC 20/60 and two LISP (single-user) machines (several more are expected in the near future). The presence of the DEC 20/60 has made possible the upgrading of our large (300 students) undergraduate core subject in Structure and Interpretation of Computer Programs (formerly 6.031) to the expanded form 6.001, which includes a substantially increased "hands-on programming laboratory" segment of about three hours per week. In addition, the DEC machine is being used for other computer science subjects for which facilities have been inadequate in the past; and the LISP machines, with their unusually powerful graphics capability, will provide the vehicle for new developments in computer aids to instruction in electromagnetic theory (6.013, 6.014). It is expected that the LISP machines and the old PDP 1140 (now released from 6.031 service) will permit the use of significantly more computation in the Department's subjects outside of the computer science field. Combined with the expanding network developments in some of the laboratories associated with the Department, the new facility dramatically improves the computational environment available to students and faculty alike.

Because of the uniqueness of our own undergraduate program in computer science and the diversity of undergraduate programs elsewhere, it has become evident that we must provide a set of first-year graduate-level "core" subjects which defines the area effectively, and in breadth, for the wide range of student backgrounds we encounter among our entering graduate students. To this end we are developing four subjects covering the following topics: 1) Programming Languages, 2) Computer Architecture, 3) Computer Science Theory, 4) Artificial Intelligence. These subjects are expected to be offered in the fall term of 1981.

The Bernard Marshall Gordon Professorship of Engineering Innovation and Practice is designed to provide a mechanism which can bring to electrical engineering students the kinds of skills and attitudes necessary for the design and development of new products in the atmosphere of the smaller company. Culminating a year-long search for persons with more than 10 years of product-design experience, and currently so engaged, who might be qualified to carry the important concepts to our students, we formulated a team solution. Stanley M. Rich, coming directly from industry to an appointment as a Gordon adjunct professor (part-time), will work with Professor William M. Schreiber of our own Department, who will also devote part of his time to a Gordon professorship, to offer a new "product development workshop" for graduate and selected undergraduate students, starting in fall 1980. In planning for this workshop, Professors Rich and Schreiber have the benefit of the specific experience of Jerome Levy, acting as consultant, in the area of education and training of engineering and technical personnel in industry and government. Professor Schreiber will also work with faculty in charge of our large undergraduate core subjects to inject, where possible, some of the ideas and attitudes of product design into the demonstrations, homework assignments, and laboratory exercises included in those subjects.

On the research front, significant actions have been taken by the Department in three areas: 1) the major thrust into Very Large Scale Integrated (VLSI) Systems has been expanded by receipt of support from the Defense Department's Advanced Research Projects Agency (DARPA) at the level of about \$1.3 million annually for two years, to cover work spanning several inter-departmental laboratories, and a range of topics from automated design to submicron technology. Under the direction of Professor Paul Penfield, Jr., this DARPA project forms but a part of a developing integrated-circuit community at MIT which involves weekly seminars, special conferences (two during the past year), an internal memorandum series, and the development of joint research proposals. As this community has crystallized, it has become clear that we must include on campus a major LSI fabrication facility capable of making state-of-the-art integrated-system chips. Such a facility is essential to the education of electrical engineering and computer science students of the future, and to the viability of a major automated-design program on one hand, and a submicron structures and technology program on the other. The entire project, to provide such a fabrication facility and place it close to the related activities with which it must couple, involves a net area of 28,000 sq. ft., capital costs of about \$14 million, and annual operating expenses of about \$3 million. The latter includes provision for annual costs of six engineers, five technicians, thirteen operators, and a secretary. In January 1980, Dr. Paul Gray announced MIT's commitment to pursue space and funding for this project, and detailed plans for the physical facilities and fund raising are now well advanced. Solicitations are already under way, and every effort is being made to bring the enterprise on line in 1982. 2) With the arrival on the faculty of Professor Erich Ippen in September 1980, and the efforts of Professors Hermann Haus and Michael Salour during the past two years, the Department's thrust into the new field of picosecond optics is assured. Professor Salour's laboratory is

already in the forefront of measurement technology in the field, and Professor Ippen's facilities are securely under way, both under the auspices of the Research Laboratory of Electronics. 3) With the naming of Professor James R. Melcher as director of the High Voltage Research Laboratory, and Dr. Chathan M. Cooke's designation as associate director, the Department's tradition of strength in this field under its previous director, Professor John G. Trump, Emeritus will be continued. A new associate professor, Marcus F. Zahn, will join the faculty and the High Voltage Research Laboratory in the coming year, and the new organization is expected to couple strongly to other MIT efforts, such as the Electric Power Systems Engineering Laboratory, the Energy Laboratory, the Center for Materials Science and Engineering, the Laboratory for Manufacturing and Productivity, and the Continuum Electromechanics Laboratory.

Undergraduate Program

Enrollment of undergraduates averaged 975 in 1979-80, and is expected to be about 1,000 next year. Further increases in the size of the Department's faculty have helped to alleviate some of the pressure produced by the enrollment growth of past years.

The third (out of four, ultimately) common-core subjects will go into place in fall term 1980. The new subject, 6.001, will be a modification and expansion of 6.031 Structure and Interpretation of Computer Programs.

The Undergraduate Educational Policy Committee will be chaired by Professor John G. Kassakian beginning this fall.

The Ernst A. Guillemin Prize for the outstanding undergraduate thesis in Electrical Engineering was awarded to Lawrence E. DeMar of Chicago, Illinois. The Computer Systems Prize for the outstanding undergraduate thesis in Computer Systems was awarded to James P. Jackson of Tucson, Arizona.

A General Motors Scholarship was awarded to James R. McLaughlin of St. Louis, Missouri.

Two Eastman Kodak scholarships were awarded to the Department this year. The recipients were John M. Canning of Sunnyvale, California, and Michael A. Isnardi of Fort Lee, New Jersey.

The Honeywell Award for Outstanding Achievement in Engineering was awarded to Tso Yee Fan of Manhattan, Kansas.

Graduate Program

In September 1979, there were 533 graduate students enrolled in the Department. Of this number, 155 were newly admitted students. About 20 percent of the total were foreign nationals. The Department supported 224 research assistants, 89 teaching assistants and awarded 15 fellowships. In addition, there were 12 National Science Foundation Fellows and 22 Hertz Fellows. The remaining students had industrial or foreign government support or were using their own funds.

During 1979-80, the Department awarded the following graduate degrees: 120 Masters of Science, 25 Electrical Engineers, and 50 Doctors of Philosophy.

The Department received over 1,275 applications for the 1980-81 year, the largest number we have had. The applicants were generally excellent and about 250 were admitted, of whom we expect 160 to register next fall.

Graduate students Robert Leong, Larry R. Carley, and Kevin G. Rhoads were given Supervised Investors Services, Inc. Awards for outstanding teaching performance by graduate students in the Department of Electrical Engineering and Computer Science. The Carlton E. Tucker Award for Excellence in Teaching, which carried the same citation, was won by Emily Roth.

The Department of Electrical Engineering and Computer Science Special Service Award in appreciation of meritorious service to the Department was given to Jeffrey I. Schiller.

Cooperative Program (VI-A)

Student enthusiasm for the VI-A Program continued unabated. The largest number ever, 168, applied for admission -- up from the previous high reached in 1978. The participating companies listed 110 openings of which 97 were ultimately filled. Cumulatively, the VI-A enrollment for academic 1980-81 will be the highest since the Program started 63 years ago.

Although demand from students wanting to join VI-A continues upward and requests from many companies to participate continue to come in, expansion is limited by the already high load the program is placing on the Department's faculty, both as VI-A faculty advisors and as thesis supervisors. This load is also starting to have its effect on the Department's graduate admissions policy, as a greater number of VI-As qualify for admission to the combined S.B./S.M. plan inherent in the VI-A Program.

Consequently, only one new company was added, along with two divisions of already participating companies.

The new company added was Medtronic, Inc. of Minneapolis, Minnesota, a medical instrumentation firm with which several of our biomedical engineering faculty have acted as consultants.

With the Department's expanded interest in the field of integrated circuits, IBM Corporation's General Technology Division in Burlington, Vermont was a new division added. Motorola, Inc. was also allowed to add its newly acquired firm of Codex Corp., Mansfield, Massachusetts, where one of Motorola's Communications Division students expressed an interest in pursuing his graduate VI-A work assignments.

For the second year, the entire selection process was successfully handled with a computer interface, which allowed the final selection of new students to be completed several weeks earlier than in the past.

RESEARCH

Most research is performed in Departmental or interdepartmental laboratories. Information on their work appears in portions of this report dealing with the following laboratories: the Electric Power Systems Engineering Laboratory (EPSEL), the Research Laboratory of Electronics (RLE), the Laboratory for Computer Science (LCS), the Artificial Intelligence (AI) Laboratory, the Energy Laboratory, the Laboratory for Information and Decision Systems (LIDS), the Operations Research (OR) Center, and the Center for Materials Science and Engineering (CMSE).

The following research groups are otherwise unaffiliated: Continuum Electromechanics Laboratory, High Voltage Research Laboratory, and MIT Stroboscopic Light Laboratory. Highlights of this year's research from these groups is reported here.

Continuum Electromechanics Laboratory (J.R. Melcher)

With a common theme of interactions between electromagnetic fields and ponderable media, projects generally have both basic and practical goals.

Based on a facility that they are developing for the computer control and analysis of dynamic testing, Professor Alan J. Grodzinsky and his students are using mechanical spectroscopy to characterize electro-rheological properties of articular cartilage. This work is part of a collaborative project with Children's Hospital (Boston) and Rensselaer Polytechnic Institute (RPI, Troy, New York) to compare healthy with osteoarthritic cartilage. Electromechanical forces have been found to contribute almost half of the stiffness of normal cartilage over a wide range of loading frequencies, under physiological conditions. Other ongoing projects include the development of an electric field-controlled membrane transport system using charged polyelectrolyte-based membranes.

Professor Melcher and his students are carrying out projects relating to environmental control for developing conventional energy systems and the use of electric fields in manufacturing processing.

In collaboration with the Energy Laboratory, a facility has been constructed for the testing of air pollution control systems up to temperatures of 1100°F. Electropacked beds have been demonstrated to have good filtration efficiencies up to this temperature with reasonable power requirements in applications such as the atmospheric pressure fluidized bed combustor. In collaboration with the Electric Power Systems Engineering Laboratory, fundamental processes contributing to the precipitation contamination of high voltage d-c transmission line insulators have been identified. In conjunction with the Polymer Processing Program, electrophoretic deposition of particules from semi-insulating plasticizers under high electric stress has been investigated as a basis for making polymer coatings. From this work has resulted a method of pumping semi-insulating liquids in insulating conduits as well as the impetus for an investigation of non-equilibrium double-layers.

Stroboscopic Light Laboratory (H.E. Edgerton)

An elapsed-time underwater camera, built with funds from the Research Committee of the National Geographic Society, was loaned to Kjell Sandved and Dr. Porter Kier of the Smithsonian Institution in February for work investigating marine invertebrates in Carrie Bow Cay, Belise, and British Honduras. They report that several new facts were observed and will be presented later in a technical paper.

Several expeditions were made to Florida with a plankton camera, in cooperation with Dr. Peter Ortner of NOAA, Virginia Key, Miami. A system was evolved for concentrating and then photographing plankton as a function of depth. Numerous profiles of the population of copepods and other plankton populations were studied also as a function of depth. These results are of great interest to sound experimenters since the plankton are dense enough to present layers of sonar response.

In June, a summer seminar on high-speed photography and videography was held. Twenty-three students attended and represented sections of the government, schools, and industries. Guest lecturers came from around the United States.

Work continues on the study of lamp circuits and components, with a particular interest in optimizing overall efficiency of light output and power source input. Improved methods of measuring rapidly varying speeds by doppler radar, with correlation by multiframe photography, are being evaluated.

High Voltage Research Laboratory (J.R. Melcher, C.M. Cooke)

Studies in the past year at the High Voltage Research Laboratory (HVRL) have involved fundamental investigations and the design of practical apparatus. In a joint project with industry to develop improved electric power transmission systems, the insulation components for a 600 kilovolt DC cable are being designed and tested at the laboratory. This new transmission cable employs pressurized gas insulation to achieve high-power capacity while being compact and reliable. The use of energetic electrons accelerated by high voltages was also pursued. Covering several years of pioneering work at HVRL, a major seminar on "Electron Disinfection of Municipal Sludge for Beneficial Disposal" was held in June 1980. Extensive biological testing, including results from an irradiation test facility at Boston's Deer Island treatment plant, have shown the required inactivation can be achieved continuously on-line by moderate doses of electrons in the megavolt energy range. This treatment process appears sufficiently promising that it is being considered and adopted by several municipalities. Electron irradiation studies for other purposes, such as the breakdown of toxic chemicals and for cancer therapy, have also been emphasized during the past year.

FACULTY

Faculty promotions within the Department included Jin Au Kong to full professor and Peter Szolovits to associate professor.

Dr. Randall Davis was appointed Esther and Harold E. Edgerton Assistant Professor of Electrical Engineering and Computer Science for two years.

Joining our faculty this year are Dr. Lance A. Glasser, formerly a research associate in the Research Laboratory of Electronics, now assistant professor in Electrical Engineering; Dr. Robert H. Halstead, Jr., who received his Ph.D. at MIT and is now assistant professor of Computer Science; Dr. Erich P. Ippen, formerly with Bell Telephone Laboratories, recently a visiting professor at MIT, now professor of Electrical Engineering; Dr. Jeffrey H. Lang, who received his Ph.D. at MIT, and has been on leave of absence at the Charles Stark Draper Laboratory during his first term as assistant professor of Electrical Engineering; Dr. Bernard C. Levy, formerly a research associate in the Laboratory for Information and Decision Systems, now assistant professor of Electrical Engineering; Dr. L. Rafael Reif, formerly visiting assistant professor at Stanford University, now assistant professor of Electrical Engineering; Dr. Campbell L. Searle, formerly Clarence Joseph Lebel Professor of Electrical Engineering at MIT, more recently professor of Bioengineering at Queens University, Canada, now professor of Electrical Engineering; Dr. Robert R. Tenney, who received his Ph.D. at MIT, now assistant professor of Electrical Engineering; Dr. John L. Wyatt, who formerly held a postdoctoral faculty position at the Medical College of Virginia, now assistant professor of Electrical Engineering.

Dr. Mildred S. Dresselhaus, Abby Rockefeller Mauzé Professor of Electrical Engineering and director of the Center for Materials Science and Engineering, received the 1980 Graduate Student Council Award for outstanding teaching. Dr. Jeffrey H. Shapiro, associate professor of Electrical Engineering, received the 1979 Graduate Student Council Award for outstanding graduate teaching. Assistant Professor Michael M. Salour was awarded a Sloan Fellowship for Basic Research by the Alfred P. Sloan Foundation. Alan S. Willsky, associate professor of Electrical Engineering and assistant director of the Laboratory for Information and Decision Systems, received the 1980 Browder J. Thompson Memorial Prize from the Institute of Electrical and Electronics Engineers for his paper, "Relationships Between Digital Signal Processing and Control and Estimation Theory." Gerald L. Wilson, Head of the Department of Electrical Engineering and Computer Science, and Philip Sporn Professor of Engineering Processing, was elected to the National Academy of Engineering for "contribution to the design and control of electric power systems under emergency conditions."

The Department was happy to welcome the following visiting faculty during the academic year. Visiting Professor Dieter Filbert came as part of the MIT/Technical University of Berlin Exchange Program, to work with Professor J.L. Kirtley, in the Electric Power Systems Engineering Laboratory. Visiting Associate Professor Lloyd J. Griffiths spent his sabbatical from the University of Colorado working with Professors Alan Oppenheim, Arthur Baggeroer and James McClellan in the Research Laboratory of Electronics. Visiting Assistant Professor Hyde M. Merrill, a consulting engineer with Dopazo, Merrill, and Sasson, developed and taught a subject, Technology Assessment and Planning for Energy and Electric Power Systems, with Dr. Thomas H. Lee, a visiting scholar from General Electric. Visiting Associate Professor Dietrich Naunin came as part of the MIT/Technical University of Berlin Exchange Program, and collaborated with Professor Kassakian in the Electric Power Systems Engineering Laboratory. Finally, Visiting Professor Eugene Wong, on sabbatical from the University of California at Berkeley, worked in the Laboratory for Information and Decision Systems with Professor S.K. Mitter on stochastic systems and data-base systems.

Department faculty who were away during the year include: Professor Abraham Bers, who spent his sabbatical leave in France, teaching and doing research at Ecole Polytechnique and at the University of Paris-Sud, Orsay, with the Department Des Gaz Ionises.

Professor Gerald P. Dinneen, whose leave of absence has been extended for a third year as Assistant Secretary of Defense.

Professor Jeffrey H. Lang, who has been on leave of absence at the Charles Stark Draper Laboratory during his first term, spring 1980.

Professor Marvin L. Minsky, who was on sabbatical leave at the Petroleum Science Department of Schlumberger Research Center, Ridgefield, Connecticut.

Professor Cardinal A. Warde, who was on leave for the academic year at the Lincoln Laboratory, conducting research with the Advanced Techniques in Systems Group.

Department of Materials Science and Engineering

Professor Joseph Weizenbaum, who took a leave of absence in Germany, teaching, doing research, and giving many guest lectures both at Berlin Technical University and in Hamburg.

Professor John M. Wozencraft, whose leave of absence was continued so he might continue to develop a masters degree program at the Naval Postgraduate School in Monterey, California.

Resignations from the Department included Assistant Professor Timothy L. Johnson and Assistant Professor Liba Svobodova.

There were no faculty retirements this year.

The Department was saddened by two deaths: Harold L. Hazen, Professor Emeritus of Electrical Engineering, and Dean Emeritus of the Graduate School, an internationally known engineering educator, who served as Head of the Department from 1938 to 1952.

Murray F. Gardner, Professor Emeritus of Electrical Engineering, who was known worldwide as an expert in operational circuit analysis.

GERALD L. WILSON

Department of Materials Science and Engineering

The marked increase in enrollment in the School of Engineering in recent years was paralleled by an upswing in registration in the Department of Materials Science and Engineering which began a year or two later than in other engineering departments. Correspondingly, our registration has continued to rise after student enrollments elsewhere have begun to level off. Our undergraduate and graduate populations increased by 11 percent and 6 percent respectively during the past academic year to record levels in the postwar history of the Department. Preregistration data for the fall semester indicate continuation of this rapid growth, particularly in our graduate programs.

Such growth has undoubtedly been fostered by heightened awareness of the many technologies and national needs which are materials-limited. Energy conversion systems, transportation, and dwindling resources are but a few areas in which materials figure prominently and which have recently been given national publicity. Our graduates have, accordingly, been much in demand. Indeed, many materials departments have experienced difficulty in filling their quotas for new graduate students because of the competing lure of an exceptionally strong job market. The accelerated growth of our graduate program is all the more remarkable in this context.

Our success has created its own set of problems. Classes have swollen to a size such that it is necessary to travel to more distant reaches of the Institute in order to find rooms of sufficient size. The physical separation of classrooms from proximity to a vigorous research program has changed the ambience of our teaching activity. Some classes have undergone a subtle change from cabaret-style lecturing to the more formal presentation required for a group of increased size. The sharp rise in enrollment has increased the responsibilities of the faculty in both teaching and research. The Department has made several appointments at the junior faculty level in response to these pressures, and increased by two the number of teaching assistants. Severe problems exist in locating suitable office space within the Department for junior faculty and new graduate students. Our research support has expanded by 10 percent in parallel with the increased numbers of graduate students. New research programs often find the lack of adequate space to be a more severe constraint than lack of available research support. Our growth has led to a tone of excitement and promise in the programs of the Department; so, in many ways, the above problems are symptoms of a happy situation. Nevertheless, they remain serious problems and the prognosis for the academic year 1980-81 indicates that they will heighten rather than abate.

Undergraduate Program

The number of undergraduate students registered in the Department increased from 110 to 122 in the past academic year. The percentage of representatives of minority groups grew slightly from the 13 percent level of the preceding report and now includes five black students. No fewer than 35 percent of our undergraduates are women, a higher percentage than in any other department in the School of Engineering. The stereotype of the engineer as male appears to have been severely dented, if not demolished, in the field of materials science and engineering.

Student interest in Course IIIB, the Department's Cooperative Work-Study Program, has continued to increase. Forty-eight students (39 percent of our undergraduate body) participated in the program and were placed at 30 different companies representing a broad cross section of industry. The academic requirements for the IIIB degree remain the same as those in the normal undergraduate program except that projects completed during the two summer assignments are accepted in place of 3.082 (a project laboratory) and the undergraduate thesis. Ten students have elected to continue the program into a fifth year for a combined S.B./S.M. Regard for the program is high among students and the sponsoring companies. Its remarkable success is due to the continuing commitment and hard work of Professor Thomas B. King who advises and administers the program virtually single-handedly. We hope to relieve him of a portion of this burden during the forthcoming academic year.

The enrollment in 3.091 Introduction to Solid State Chemistry, which had increased from 474 to 550 in previous years, remained essentially constant at 526 during 1979-80. The majority of freshmen at MIT continues to satisfy the Institute Chemistry Requirement by attending the 3.091 lectures given by Professors August F. Witt and Robert M. Rose. The major portion of the recitation sections is conducted by faculty members. Registration in the required subjects in the undergraduate curriculum has risen to an average level of 50. The increase has been most dramatic in the case of 3.081 Materials Laboratory I, taught by Professor Robert E. Ogilvie. Designed to permit the operation of x-ray and electron-optic apparatus by three or four small groups of students, enrollment exceeded 40 in the spring of 1978 and 63 in the spring of 1979. Initial registration grew to the alarming level of 115 during the past academic year. We were reluctant to limit enrollment in a subject which is required in our curriculum and may be taken by students in other departments to satisfy the Institute Laboratory Requirement. Laboratory sessions were thus scheduled in the evening as well as on weekday afternoons. The popularity of the laboratory may be measured by the fact that there were very few student desertions under this ad hoc arrangement. During the 1980-81 academic year the Department will have no alternative other than to offer 3.081 in both the fall and spring semesters. Additional teaching assistants have been allocated to assist in the task. Limited funds have been obtained to permit refurbishment of some of the equipment in this laboratory, much of which is over 30 years old. Attempts to secure more substantial grants to provide sorely needed major replacements have been met largely with frustration.

Several changes have been made in the undergraduate requirements. In response to suggestions made by the MIT Corporation's Visiting Committee and also by the accreditation team of the Engineers' Council for Professional Development (ECPD), 18.03 Differential Equations, has been added as a required subject. In the recent past virtually all of our students had taken the subject as an elective prior to entering the Department. Reinstatement of this subject is a more formal recognition of the importance which the Department attaches to the subject. To accommodate 18.03 among the requirements, 3.10 Chemical Physics of Materials was changed from a required subject to a restricted elective, and four rather than five subjects are now required in this category. A subject with engineering emphasis, 3.16 Applied Surface Chemistry, has also been added to the list of restricted electives. An additional subject concerned with heat and mass flow in materials processing is under development for possible later inclusion. The Undergraduate Committee closely monitors the restricted elective portion of the curriculum to ensure that its structure does not allow a) narrow specialization, b) escape from some exposure to elements of both the science and engineering of materials, or c) contact with less than two of the major classes of materials.

Beginning with the 1980-81 academic year a portion of the units presently required for undergraduate theses will be devoted to 3.041 Thesis Seminar. We hope that through short presentations on their thesis research, students will gain experience in oral presentation and also gain some familiarity with the range of research performed within the Department. These presentations

will occur during the latter part of the semester. The early weeks will be devoted to instruction in such areas as safety procedures, technical writing, and data analysis -- topics which often escape coverage in the curriculum.

Relations between faculty and undergraduate students remain excellent in the Department. Such interactions are fostered by regular social hours which are well attended. Four students serve as members of the Department Undergraduate Committee. Undergraduates continue to be closely involved with faculty in research; in addition to undergraduate thesis research 78 UROP projects were performed by our students during the academic year, 22 for academic credit, 56 for compensation. We are pleased to report that Susan Shakin, one of our students, was chosen to receive the 1980 Alumnae Senior Academic Award of the Association of MIT Alumnae (AMITA).

Graduate Program

The number of graduate students in the Department in 1979-80 reached an all-time high of 172. This record promises to be short-lived. Based on acceptances of admission we expect an even more dramatic increase to 215 for the academic year 1980-81. Of the students currently enrolled, 107 (62 percent) are supported by research assistantships. Twenty-one hold fellowships. Citizens of the United States represent 62 percent of the graduate student body. Twenty-six students (15 percent) are women. Although the latter figure is not as high as the proportion of women in the undergraduate program, it seems likely to increase sharply as a portion of our present undergraduates move on to graduate study.

Graduate activities in the Department are grouped into five degree programs. Three deal with the integrated science and engineering of a specific class of material: ceramics, metallurgy, and polymerics. The two remaining fields concentrate on either the science of materials or the engineering of materials, and thus cut across several classes of materials. Each program is overseen by a faculty panel. The structure is not compartmentalized, as faculty in the Department commonly serve on two or even more panels and faculty from outside the Department also serve as panel members. Each of the programs is vigorous and in the past year we have approached a satisfactory balance between the student enrollment in each. The graduate enrollment in the ceramics, metallurgy, and materials science programs at the end of the 1979-80 academic year was 36, 43, and 36, respectively. The newer programs, materials engineering and polymers have seen enrollments grow to 21 and 26, strengths which are now comparable to our more established programs.

Two new subjects, 3.33 Defects in Crystals, and 3.34 Advanced Physical Metallurgy, were introduced in the graduate curriculum by Professor Robert W. Balluffi who joined the Department in September 1978. Professor Gregory J. Yurek introduced 3.541 Oxidation and Corrosion of Materials at Elevated Temperatures.

Ronald O'Malley was awarded the Department's John Wulff Award for outstanding service by a teaching assistant. The Award commemorates the contributions of Professor Wulff, a lecturer of legendary prowess in the Department. It is gratifying that a group of alumni is at work to establish a permanent endowment for continuation of the Award. The Falih N. Darmara Award for outstanding academic achievement, research, and extracurricular activities was presented jointly to Charles Ashdown and Ignatius Britto.

A total of 58 graduate degrees were awarded by the Department of which 25 were doctorates. Eight master's degrees and two of the doctorates were awarded to women.

RESEARCH

The academic year 1979-80 saw an increase in the research activity within the Department at a level just under \$6 million per annum. This support is derived from a variety of agencies, prominent among them the US Department of Energy, various branches of the Department of Defense, and the National Science Foundation. Support from the latter is received directly, as well as through the Center for Materials Science and Engineering at MIT. A number of our

faculty participate in the research groups supported by the Center and contribute to its overall operation through the supervision of central facilities. A great deal of collaboration exists as well with the Energy Laboratory. We also enjoy considerable support from a broad range of industries. This is sometimes in the form of student fellowships or faculty development awards, but includes a generous measure of direct support of research projects.

The research programs of the Department are rich, lively, and varied. They mirror the spectrum of interests present in our teaching activities, extending from theoretical studies of electronic structure and the atomic-scale structure of crystalline and amorphous solids, through study of structure on a coarser scale and its interplay with useful properties, to a concern with the processing and performance of end products and productivity. The Department is fortunate in having expertise and vitality throughout this range. The breadth of this research makes it difficult to single out even a few highlights for separate mention. In any case, this is probably unnecessary as a description of the research activity of each faculty member is contained in considerable detail among the contributions to the annual MIT Report of the Center for Materials Science and Engineering (January 1980).

It seems appropriate to make a few general observations on the character and organization of this activity. The Department is strongly oriented toward research. The necessity for continuity, adequate supervision of students, and the completion on schedule of some of the more mission-oriented projects gave rise in the recent past to a growth in our full-time research staff. Our faculty has given much thought to maintaining proper balance between staff research, student research, and teaching. We feel that thus far this has been maintained. The bulk of our research is still performed by graduate students and the tendency for undergraduate students to become involved in research early in their careers has, if anything, increased. The large number of UROP projects performed in the Department has already been mentioned. In addition, the faculty provides part-time research employment or summer jobs. The availability of full-time staff to assist in supervision seems to have expedited this involvement.

The limitations of material performance in many components necessary to solve today's problems have led to a resurgence of interest in processing. Processing involves not only the efficient and economic production of components of a requisite size and shape but is the final stage in determining structure and, hence, the properties of the device. Activity in processing all of the classes of materials of interest in the Department had grown to a level that we felt the need for an organization to facilitate communication and interaction between groups, and to coordinate initiatives for dealing with industrial and Federal groups in the attack of complex, large-scale problems. The formulation of plans for such an organization was described in last year's report. The formation of the Materials Processing Center was announced in August 1979 by Dean Robert Seamans with Professor Merton C. Flemings as director. The Center was inaugurated on February 1, 1980 with a special colloquium organized around the theme "Materials Processing -- An Ancient Art, a New Technology." Leading materials scientists and engineers from government, industry, and academia participated in the program.

Another area of national concern is the efficient use of the dwindling supply of natural resources. Many dangers accompany a nation's becoming heavily dependent upon external sources for materials that are essential to its economic well-being. In response to such concern the Department of the Interior established 22 institutes under the Surface Mining and Reclamation Act of 1977. The MIT Mining and Minerals Resources Research Institute (MMRRI) was established in late 1978 with Professor John F. Elliott as director. The Institute is charged with the support of training and research in mining and mineral resources. Research programs are being developed in areas such as the exploration, extraction, processing, and development of mineral resources; mining and mineral technology; and the economic, legal, and social aspects of mineral reclamation. In the past year MMRRI has established communication with the MIT community through a regular newsletter and has introduced subjects in mining and mineral technology. Research has been initiated in a number of departments at the Institute.

FACULTY

In the past year Professor David K. Roylance was awarded tenure. Three assistant professors, Rowland M. Cannon in ceramics, Thomas W. Eager in materials engineering, and Gregory J. Yurek in metallurgy, will be promoted to associate professor (untenured).

Alan Bleier, a colloid chemist who was previously associated with Union Carbide, joined the ceramic processing activity as assistant professor in January 1980. Upon completion of his doctorate in metallurgy in this Department, I-Wei Chen was appointed assistant professor in nuclear materials and materials engineering jointly with the Department of Nuclear Engineering. He assumed the position in January 1980.

Two search committees active during the 1979-80 academic year nominated candidates for junior faculty positions. A committee chaired by Professor Frederick J. McGarry nominated Gary Wnek to fill the position of assistant professor in our expanding activity in polymerics. Mr. Wnek, who is completing his doctorate at the University of Massachusetts at Amherst, will join the Department in September 1980. A second committee, chaired by Professor Elliott, recommended Terry Ring for an assistant professorship in mineral engineering upon completion of his doctoral work at Cambridge University. Mr. Ring, who will join the Department in August 1980, will be closely associated with the activities of the newly-established Mining and Minerals Resources Research Institute at MIT. A third committee has not yet completed its search.

Professors Robert M. Rose and W. David Kingery were on sabbatical leave in the fall and spring semesters, respectively. Professor Walter S. Owen, Head of the Department, will be on sabbatical leave during the summer and fall semester of the 1980-81 academic year. Professor Bernhardt J. Wuensch has been appointed Acting Head during this absence.

The Department welcomed three visiting faculty during the past academic year. Professor Jeun Heh, Head of Mechanical Engineering Department, Chung Cheng Institute in Taiwan served as visiting professor from January through April. Professor Itaru Niimi, Managing Director, Toyoto Motor Co., Japan was associated with the Materials Processing Center as visiting professor of materials engineering. Professor Floyd Tuler collaborated with Professor Herbert H. Hollomon at the Center for Policy Alternatives and with Professor Joel P. Clark of our Department as visiting associate professor while on leave from Hebrew University.

The Materials Science and Engineering faculty have continued to hold leadership roles in their respective professional societies and in a range of government committees and panels. They have accordingly been recipients of a number of significant awards and honors, only a few of which may be singled out for mention here.

Professor Nicholas J. Grant was elected to the National Academy of Engineering and was, in addition, appointed Krumb Lecturer of the AIME for 1979-80.

Professor Flemings was elected to the American Academy of Arts and Sciences, and received the 1980 John Chipman Award of the American Institute of Mining, Metallurgical, and Petroleum Engineers (AIME).

Professor Owen was elected to the New York Academy of Sciences, and was awarded an honorary professorship at Shanghai Jiao Tong University in the People's Republic of China.

Professor Morris Cohen was elected Foreign Fellow, Indian National Science Academy and to honorary membership in The Metals Society, London. He further received honorary professorships at the Beijing University of Iron and Steel Technology and at the Beijing Institute of Aeronautics and Astronautics in the People's Republic of China.

A number of the ceramics faculty received prominent awards from their professional society. Professor Kingery was the 1980 Orton Lecturer of the American Ceramic Society. Professor H. Kent Bowen received the American Ceramic Society's Schwartzwalder-PACE Award as the nation's outstanding young ceramic engineer. He was, in addition, elected a Fellow of the Society. Professor Donald R. Uhlmann received the F.H. Norton Award as the Distinguished Ceramist in New England, while Professor Robert L. Coble was elected Distinguished Lecturer

of the Northern Ohio Section of the American Ceramic Society.

The American Welding Society presented the District Meritorious Certificate Award to Professor Koichi Masubuchi and the Adams Memorial Membership Award to Professor Thomas W. Eagar.

Professor Roy Kaplow was awarded the Kurtz Lectureship. The American Society for Metals elected Professor Regis M.N. Pelloux as Fellow.

BERNHARDT J. WUENSCH

Department of Mechanical Engineering

INTRODUCTION

The year 1980, the centennial year of the American Society of Mechanical Engineers, marks the beginning of an era of change in which the mechanical engineering profession has unprecedented opportunity and challenge in helping to solve many of the most serious problems society faces. Among the more important of these are: providing energy sources alternative to petroleum and natural gas, conserving energy and other natural resources, controlling environmental pollution, providing health care and human rehabilitation, supplying efficient transportation, and enhancing industrial innovation and productivity. With its broad disciplinary base and design orientation, an education in mechanical engineering provides a versatile background both for professional practice in engineering and for further study and subsequent practice in fields such as medicine, law, management, education, or public policy.

However, it is clear that in the next decade and beyond, the nature of mechanical engineering practice and the knowledge, skills, and insights needed by members of the profession will change significantly. The growing scarcity and cost of conventional resources; the revolution in information, computation and automation; and the pressing need for technology to interact positively with social, economic, legal, and political institutions, as well as with the public, constitute powerful driving forces for change. Providing foresight and leadership in developing and implementing the new curricula and programs needed to prepare students to be leaders in shaping future technology is perhaps the greatest challenge facing mechanical engineering educators in the coming decade. Unfortunately, this challenge comes at a time when mechanical engineering enrollments are high and academic budgets stringent, faculty workloads are heavy, and the pool of highly talented faculty candidates is insufficient to meet national needs.

In this Department, undergraduate enrollment appears to have stabilized at slightly more than 400 following a three-fold increase in the 1970s. Graduate enrollment has continued to grow more slowly, rising by 7 percent last year to reach 334. The School-wide Engineering Internship Program (EIP), which leads to both the S.B. and the S.M., with employment and thesis research at a cooperating company, has proved to be a valuable addition to the Department's academic program, especially for students interested in industrial careers. About half of the 108 students in the EIP are mechanical engineers and are placed in 19 of the 31 participating companies.

For the first time in several years the Department experienced flexibility in allocating faculty effort to planning and development of curricula and new text material. This year 13 new or revised subjects were planned or introduced into the graduate curriculum, and a major revision of the undergraduate subject in the mechanical behavior of solids was developed for introduction next year. Several faculty worked on new textbook projects.

The most notable graduate course development this year was 2.64 Synthetic Fuel Production (A) under the leadership of Professor Ronald F. Probst. The course attracted students primarily from chemical and mechanical engineering. A new Academic Policy Committee was formed to plan new curricula and programs which will meet the changing needs of the profession, as well as

insuring quality control and coherence of the existing educational program. The Committee is discussed in greater detail in the section on "Programs of Instruction."

The Joint Computer Facility was expanded significantly this year through additional memory and disk drives. A data link was established with the Computervision Computer-Aided Design System for research and educational activities in computer-aided drafting, engineering analysis using interactive graphics, and engineering design. Professor Derek Rowell has provided extraordinary service to the four participating Departments (Aeronautics and Astronautics, Civil, Mechanical, and Ocean engineering) through his technical and managerial leadership of the design and implementation of this vital facility.

Research volume in the Department and cooperating interdisciplinary laboratories and centers conducted by faculty and staff is projected to increase about 10 percent to \$12.4 million. The Department has made further progress toward its goal of fostering strong relationships with industry and other non-Federal institutions. About 30 percent of sponsored research derives from non-Federal sources. The Laboratory for Manufacturing and Productivity and the Sloan Automotive Laboratory are now approaching 50 percent industrial support. Further details are provided in the section on "Research" later in this report.

During the year several important planning and development activities were under way which will lead to new research and new major facilities. Under the auspices of the Dean of Engineering, Professor Herbert H. Richardson chaired an interdepartmental Ad Hoc Committee on Research in Automotive Technology involving several departments in the School of Engineering, the Center for Policy Alternatives, the Energy Laboratory, the Center for Transportation Studies, the Laboratory for Information and Decision Systems, and the Center for Materials Processing. Professor David N. Wormley and Dr. Malcolm A. Weiss of the Energy Laboratory chaired a working group of this Committee. The Committee examined current and potential research and educational activities related to automobile and truck technology, and recommended the establishment of four major program areas having high potential for MIT: an automotive performance program; materials, structures, and manufacturing processing program; health and environmental effects program; and automotive systems program.

Recent new efforts in mining, fracturing, and recovery of fossil fuels and other resources have led to the planning of a new Laboratory for Resource Extraction, to be run jointly with the Department of Civil Engineering.

Plans for a new Center for Engineering Design to be located in refurbished space on the fourth floor of Building 3 were reviewed by the Dean and the Department's Visiting Committee, and a final prospectus will be completed during the summer of 1980. This new Center, which will require raising capital funds, will provide a new focus for design education in light of the growing role of computer aids and interactive graphics, and the pressing need to stimulate innovation and creativity in design.

Demand for the Department's graduates at all levels remained keen with starting salaries among the highest offered in scientific and engineering fields. The strong competition from industry tended to attract MIT students with the S.B. and S.M. away from the prospect of more graduate-level education. This trend is especially pronounced in the case of blacks. Doctoral graduates, however, were in strong demand by industry and as junior faculty in other institutions.

PROGRAMS OF INSTRUCTION

Overall Objectives and Management

The Department's instructional programs are designed to educate mechanical engineers for leadership roles in professional practice and engineering education, and to provide a broad and flexible background for entering related fields such as medicine, law, management, and public policy. Both the undergraduate and graduate programs are continuously monitored, reviewed, and revised to meet the expected future needs of the profession and related fields.

The needs for curricula changes, new graduate programs, new and upgraded laboratories, and new pioneering texts and other educational materials are clear in concept but require sustained creative effort in a continuing climate of tight budgets and heavy day-to-day research and teaching commitments.

To place strong emphasis on the development needs of both undergraduate and graduate programs, as well as ensuring quality control and the efficient use of faculty resources, two steps have been taken.

First, the new Academic Policy Committee has been established and given responsibility for identifying and stimulating new curriculum developments, for reviewing existing and proposed programs and courses, and for recommending to the faculty policies regarding all aspects of the Department's academic program. The members of this Committee are Professors Joseph L. Smith, Jr., chairman; Ali S. Argon; and J. Karl Hedrick. During 1979-80 the Committee began to function in a review mode for new subjects, and concluded that the undergraduate curriculum should be reviewed and revised during the next few years in light of the expected changes in mechanical engineering practice in the remainder of the century.

Second, the position of Schedules Officer was established. The Schedules Officer, who will report to the Department Head, has responsibility for planning and optimizing teaching resources on a three-year cycle to allow flexibility in scheduling faculty time to permit course and curriculum development and the writing of new textbooks. Through this mechanism and with limited curriculum development funds provided in the Department's operating budget, several new subjects and programs are under development and several textbook writing projects are under way. Professor Ernest Rabinowicz will serve as Schedules Officer.

Undergraduate Program

Undergraduate enrollment stabilized at 409 in 1979-80 (compared with 412 in 1978-79), following a decade which saw the undergraduate population triple. In the fall of 1979, 118 sophomores entered the Department compared with 130 the previous year. A total of 117 Bachelor of Science degrees were awarded, 14 to women and seven to blacks.

Course II-A, administered by Professor Thomas B. Sheridan, attracted about 10 percent of all undergraduates enrolled in the Department. This program, which is not accredited by the Engineers' Council for Professional Development, allows students to design interdisciplinary programs which combine a strong base in mechanical engineering fundamentals with subjects from other fields relevant to the students' professional objectives. Traditionally, biomedical engineering has been the most popular area of interest for II-A students, but recently students' programs have included more diverse interests such as management, computers and computation, energy production from alternate sources, and energy policy.

The undergraduate program is managed through the Undergraduate Office by Professor David Gordon Wilson, the Undergraduate Officer, and his Assistant, Peggy Garlick. This office coordinates activities between the Department, the Registrar's and Schedules offices, and the Committee on Academic Performance. The Undergraduate Office also oversees undergraduate theses and the Department's UROP activities, as well as providing support for the student-run Pi Tau Sigma course and instructor evaluations.

This year the Office initiated a program to recognize excellence and monitor marginal performance. Students having outstanding academic performance during the academic year receive personal letters of congratulation and encouragement from the Department Head while students whose performance shows cause for concern receive letters from the Undergraduate Officer suggesting steps to be taken to avoid continuing problems. Students who appear especially qualified for graduate study are encouraged to investigate this possibility early in their undergraduate years and to consider a combined S.B./S.M. program with a single thesis.

The Undergraduate Enrollment Committee, headed by Department Instructor, Dana R. Yoerger, is responsible for presenting the Department to prospective undergraduate students. Activities included participation in the Freshman Academic Midway and Open House. The Freshman Open House attracted a large number of prospective students interested in learning about opportunities

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in the Department and in the mechanical engineering profession.

The Undergraduate Committee, headed by Professor Michael G. O'Callaghan, is a policy forum for all matters affecting undergraduate life. The Committee, composed of eight faculty members and eight student members, who represent the different classes and Department student organizations, reports directly to the Department Head. This year, the committee recommended changes in the approach to writing instruction in the Department. The Committee also recommended changes in scheduling and evaluation methods for the new two-course sequence in the mechanical behavior of materials.

The most significant development this year in the undergraduate subjects was the replacement, beginning in 1980-81, of the core subject 2.30 Mechanical Behavior of Solids (12 units), by a two-term sequence of two 9-unit subjects which include a coordinated laboratory. The goal of this new sequence, 2.31 and 2.32 Mechanical Behavior of Materials I and II, is to more strongly integrate the fundamentals of materials science and mechanics into the curriculum through a combined mechanics-materials/continuum-microscopic approach. The subjects are also intended to provide a solid basis for dealing with materials behavior and selection in design.

The Department's design subjects continued to grow in popularity, and 2.74 Advanced Mechanical Design, a restricted elective subject, was reorganized by Professor Carl R. Peterson to concentrate on machine elements in mechanical design. Students interested in design are encouraged to take this subject before the required senior subject, 2.73 Design Projects. Enrollment in undergraduate seminars, 2.S06 How Things Work and 2.S24 Computer Graphics increased substantially to 53 and 40 under the respective leadership of Professors Woodie C. Flowers and David C. Gossard. Major responsibility for teaching 2.S24 was carried by Lecturer Philip F. Meyfarth. The sophomore core subject, 2.70 Introduction to Design, also attracted a record enrollment of 180, of which 15 percent was from outside the Department. The design competition, "A Couple of Moments of Truth," which involved student-designed and fabricated vehicles competing for dominance on a pivoted beam, drew unprecedented enthusiasm both from students and the MIT community at large. Professor Flowers continued in charge of this subject.

Course 2.10 Elementary Programming and Machine Computation, grew to an enrollment of nearly 400, serving about 35 percent of MIT's freshman class. This popular subject, under Professors Warren P. Seering and John L. Bassani, uses the Joint Computer Facility (DEC VAX 11/780), mentioned earlier.

The core subject, 2.03J Dynamics was reorganized and taught by Professor James H. Williams, Jr. and Lecturer Samson S. Lee. Topics in kinematics, newtonian dynamics, lagrangian dynamics, and vibration are being developed for lumped-parameter and continuous mechanical, electrical, and electromechanical systems. Special topics include Rayleigh's Principle and gyroscopes.

Course 2.96 Management in Engineering, which is a restricted elective in the Department and an Engineering School-Wide Elective, grew to the point where it is being divided into two 50-student sections. Robert T. Lund, Senior Research Associate in the Center for Policy Alternatives and Dr. David P. Hoult, Senior Research Associate, have developed and taught this popular subject which uses case methods.

The Mechanical Engineering Undergraduate Laboratories serve the needs of undergraduates in the fields of measurement and instrumentation, control systems, mechanical behavior of materials, and manufacturing processes.

In conjunction with the curriculum changes involving the core requirements in Mechanical Behavior of Materials I and II, 2.31 and 2.32, major refurbishing of the laboratory associated with these courses has begun. About 60 percent of the \$120,000 required has been raised, and work is expected to begin this year.

Additions were made to the laboratory associated with 2.86 Manufacturing Processes Laboratory, to expand the course material to include polymer processing. State-of-the-art polymer processing machines have been acquired and installed.

The undergraduate laboratory for 2.14 Control System Principles, was upgraded in 1979 by acquiring new analog/digital computer equipment which is used for both simulation and control

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applications. A new joint laboratory facility with the Department of Electrical Engineering and Computer Science is being established by Professor Paul K. Houpt, which will result in more capability at less cost to both departments. This co-venture resulted from the deliberations of an ad hoc interdepartmental committee on automatic control.

In the area of student organizations MIT's chapter of the American Society of Mechanical Engineers continued to provide a popular forum for discussion of career opportunities. The officers for 1979-80 were Lorraine G. Olson, president; Charles S. White, vice president; Deborah A. Gabrielson, treasurer; and Anitta L. Bliss, secretary. Professor Gossard continued as faculty advisor.

Pi Tau Sigma, the mechanical engineering honorary society, continued to provide invaluable service to the Department by conducting course and instructor evaluations twice each term. The Society inducted 20 new members this year. This year's officers were John M. Dieken, president; Eugenie Hainsworth, vice president; Timothy P. Harrigan, treasurer; and Mark J. Mooradien, secretary. Professor Ernest G. Cravalho continued to serve as faculty advisor.

Black Mechanical Engineers (Black ME) is an organization of black students in the Department which provides academic help and facilitates communication among black students and the faculty. Black ME was active in recruiting minorities into the Department and provided study aids, personal tutoring, and career guidance for its members. Membership reached an all-time high of 35 students this year. The officers for fall term were Gail E. Randall, president; Robert Adu-Gyamfi, vice president; and Herbert C. Buchanan, treasurer. James E. Hubbard, Jr., served as academic officer and Byron A. Braxton was lounge coordinator. For the spring term, Adu-Gyamfi served as president, with Nathan Graham serving as vice president. Professor Stephen H. Crandall continued to serve as faculty advisor.

Many undergraduates in the Department received awards for academic excellence, engineering expertise, and community service. Among the most notable are the following: Lorraine G. Olson and Robert Schlingensiepen were the first students from the Department to be honored by election to Phi Beta Kappa, based on their academic accomplishments and interest in the humanities. James M. Karlen and Charles F. Malacaria, both seniors in the Department, were among those who accepted the William L. Stewart, Jr. Award won by Olympiad 1980 for new concepts in social programming. Named as General Motors Scholars were Michelle R. Hunt, Melissa G. Lepper, and R. Dirk Taylor. Matthew L. Russell received the Scott Paper Company Foundation Leadership Award.

For the third consecutive year J. Randolph Andrews received a Luis De Florez Award for outstanding ingenuity and creative judgment. This year he was recognized for the design and construction of a manipulator and controller for research in compliant control. His earlier awards were for a portable collapsible bicycle and a numerically controlled machine tool.

Engineering Internship Program

The School of Engineering Internship Program (EIP) completed its third year of operation with the Department as its largest participant. Professor Igor Paul continues to administer the Program for the Department. This Program leads to both the S.B. and S.M., with employment at a participating company during three summers and one academic term. A single thesis is required for both degrees with the research done on a problem of interest to the company, and conducted primarily at the company. Of our 118 sophomores, 38 applied for the EIP and 28 were admitted. Currently 51 of 108 students in the EIP are students from our Department. Reflecting the high demand for mechanical engineers by industry, students from the Department are now placed in 19 of the 31 participating companies.

This year, the first class of EIP students became seniors and applied for admission to graduate school. After attrition, five Mechanical Engineering students are entering the graduate phase of the EIP and will be working on their thesis projects during the coming academic year. To this point, the EIP appears to be an excellent addition to the Department's academic program for students interested in industrial careers. It also provides valuable new contacts between department faculty and industry and a better mutual understanding of university and industrial problems, capabilities, and strengths.

Graduate Program

Enrollment in the graduate program increased from 314 to 336; 137 new graduate students joined the Department and 130 graduated. The Department awarded 106 S.M., seven Mechanical Engineer and 24 doctorates in 1979-80. During the year, graduate degrees were awarded to six women, and three blacks, one of whom was a woman. Applications from students abroad remained at approximately the level of last year, but applications from students attending US colleges and universities increased 25 percent. Overall, about 30 percent of the Department's graduate students are foreign; however, at the doctoral level, an increasingly large proportion of successful candidates are foreign. This trend toward fewer US doctoral candidates in mechanical engineering is more pronounced in other US universities and is cause for serious national concern. Probably the most significant reasons for this trend are the intense financial competition from US industry for mechanical engineers at the S.B. and S.M. levels, the drop in salaries for doctoral level graduates relative to those for lower degree graduates, and the growing student interest in industrial practice rather than research.

Support for graduate students also increased in 1979-80. The number of students supported by the Department through research and teaching assistantships rose from 175 the previous year to 201 this year, representing 60 percent of all graduate students. Overall, 90 percent of all graduate students received support.

The graduate program was directed by Professor Warren M. Rohsenow, Graduate Officer, and his Assistant, Sandramarie Williams.

The 1979-80 academic year saw 13 new subjects added to the graduate curriculum in such fields as energy, transportation, materials, and engineering risk-benefit analysis.

Professor Probststein established a new course, 2.64 Synthetic Fuel Production (A), the only such offering at the Institute. The course was designed to prepare graduates of the Department to enter this growing field. Several special lectures by visiting experts from outside MIT brought important perspectives to the course. The course attracted students primarily from Chemical and Mechanical engineering. For the former, the course provided background in the relevant mechanical disciplines; and for the latter, background in the relevant chemical disciplines. All students were exposed to and gained an appreciation for synthetic fuel technology.

Senior Research Scientist Leon Glicksman and Professor Adel F. Sarofim of the Department of Chemical Engineering have developed a new graduate course in Fluidization, 2.65J (A). The course focuses on the use of fluidized beds for power generation, process heating, gasification and heat exchangers.

In the basic fluid mechanics area, the existing subject in viscous and turbulent flows will be replaced by a new two-term sequence, 2.272 Laminar Flows and Stability (A) and 2.273 Turbulent Flow and Transport (A). These new subjects will be offered by Professors Probststein and Ain A. Sonin, respectively.

Another new subject, Mixing and Reaction in Turbulent Flows, 2.285 (A), will be offered by Professor Stephen B. Pope. The subject develops practical models for turbulent combustion based on modern statistical theory.

Professor Myron Tribus of the Center for Advanced Engineering Study, with the support of Professor Rohsenow of the Department and Professor Jack B. Howard of the Department of Chemical Engineering, will offer a new course in Thermoeconomics, 2.45J (A). Thermoeconomics is a new method for the analysis of thermodynamic systems using economic and related optimization principles.

In the area of transportation, the Department continued to collaborate with the Center for Transportation Studies in curriculum development and graduate teaching related to transportation technology. Professor Hedrick collaborated with Professor Yosef Sheffi of the Department of Civil Engineering in developing and offering for the first time, CTS 140J (also 1.290J and 2.120J), Transportation Performance and Technology (A). This is one of several core subjects in the new MIT program leading to the S.M. in Transportation.

A new two-course sequence in polymer science and technology was initiated by Adjunct Professor Giuliana C. Tesoro of the Department, and Professor Donald R. Uhlmann of the Department of Materials Science and Engineering. The first course of the sequence, 2.926J (A), will emphasize relationships of molecular structure and chemical composition to properties in polymeric materials. The second course, 2.927J (A), will focus primarily on fundamental concepts of polymer physics, and on supra-molecular structure and its effect on polymer materials.

A new course, 2.094 Theory and Practice of Continuum Mechanics (A), was developed and offered for the first time by Professors Klaus-Jürgen Bathe and Michael P. Cleary. The purpose of the course is to combine the study of the basic principles of continuum mechanics with the special formulations used to obtain computer-based solutions to complex engineering problems.

The Project Proseminar in Technology and Policy, TPP11J (A) and TPP12J (A), was revised under Dr. Marvin A. Sirbu, Jr., Lecturer in the Department and Principal Research Associate in the Center for Policy Alternatives. The object of these revisions was to strengthen the links between the Department, the Technology and Policy S.M. Program, and the Program in Science, Technology, and Society.

Gregory C. Chisholm received the Department Student Service award for outstanding contributions to the Department and to black student life throughout the Institute.

RESEARCH

Volume and Composition

The total volume of sponsored research has grown substantially during fiscal years 1978 and 1979. In fiscal year 1977, research volume was about \$5.6 million and by the end of fiscal year 1979 had grown to about \$11.3 million (in current dollars), representing approximately \$215,000 per faculty member. Research volume for 1979-80 is projected to be about 10 percent higher than 1978-79 or about \$12.4 million. Of the total research volume, approximately 56 percent is administered through the Department with the remainder administered through interdepartmental laboratories and centers such as the Energy Laboratory, the Center for Materials Science and Engineering, the Electric Power Systems Engineering Laboratory, and the Harvard-MIT Health Sciences and Technology Program. Since 1976-77 the fraction of research conducted through these interdisciplinary laboratories has increased from 40 percent to 56 percent, reflecting the growing role of these organizations in the research activities of the faculty. The Laboratory for Manufacturing and Productivity has experienced major growth since its initiation in January 1977 and is projected to have a total research volume of \$1.8 million for 1979-80.

Unrestricted funds which enable the Department to enter new fields of research not currently popular with government agencies, to enhance career development of junior faculty, and to acquire new research equipment continue to be scarce. However, several corporations and foundations made modest unrestricted grants to the Department which proved invaluable. Several young faculty received research support from industrial career-development grants raised by the School of Engineering and the MIT Leadership Campaign.

Scope and Trends

Research conducted by the faculty and staff ranges from fundamental, generic research to engineering system development over a wide spectrum of disciplinary skills and applications that are of importance to society. This broad scope is one of the unique strengths of the Department which provides a rich environment for education and professional development of undergraduate and graduate students, as well as regular and visiting faculty and staff.

Applications-oriented research can be grouped into four principal programmatic areas: *manufacturing and processing*, *energy and environment*, *biomedical engineering*, and *systems including transportation*. The percentage of faculty members involved in research in each area is approximately 22, 28, 21, and 16 percents, respectively. A number of faculty work in more than one area. Fundamental generic research can be grouped in three disciplinary areas: *mechanics and materials*, *thermal and fluid sciences*, and *systems and control theory*. About 45 percent of the faculty are heavily involved in fundamental research in these disciplines, with primary emphasis in the first two areas. It is noted, however,

that virtually all research conducted has some fundamental generic content and therefore all the faculty have at least some involvement in fundamental generic research.

Despite stated objectives of the Federal government to strengthen basic research in engineering as well as science, funding for basic research remains difficult to obtain. Thus, much of the Department's fundamental research is supported as parts of applications-oriented programs. Examples of ongoing fundamental research conducted in the Department during the past year include: fatigue, deformation, and fracture of metals, glassy polymers, composites, and porous/geological materials (Professors Argon, Cleary, Frank A. McClintock, David M. Parks, Robert O. Ritchie, Bassani, and Williams); ignition, combustion of gas/fuel mixtures, combustion instability, turbulence modeling, and smoldering (Professors George E. Abouseif, John B. Heywood, James C. Keck, Pope, Tau-Yi Toong and William C. Unkel); tribology (Professors Rabinowicz and Nam F. Suh); fluid flow, flutter and wave propagation in collapsible tubes (Professors Roger D. Kamm and Ascher H. Shapiro); heat transfer in fluidized beds, in nucleate boiling and between immiscible fluids (Dr. Glicksman, Senior Research Scientist and Professors Borivoje B. Mikić, O'Callaghan, and Rohsenow); random vibration (Professor Crandall); computational mechanics (Professor Bathe); nonlinear control, and dynamics and control of chemical and biological systems (Professors Hedrick, Henry M. Paynter, and Alician V. Quinlan).

New Programs and Notable Accomplishments

In Biomedical Engineering Professor Ioannis V. Yannas and his collaborators at Harvard Medical School and the Shriners Burns Institute obtained encouraging results from their first clinical testing of an artificial skin on humans. This engineering membrane, which consists of an inner layer of natural collagen fibers in a mucopolysaccharide matrix and a porous polyethylene outer layer, was shown to outperform any alternate for closure of large full-thickness burns.

Professor Padmakar P. Lele continued his research in the use of hyperthermia induced by ultrasonic radiation to treat tumors. Following dramatic test results with animals, clinical tests on humans with otherwise untreatable tumors has begun, with promising results.

Professors C. Forbes Dewey, Jr., Kamm and Shapiro continued research on the fluid mechanics of human circulatory systems. Professor Dewey investigated the influence of fluid shear stress on living endothelial cells which line the arterial walls, as part of a program to understand the genesis and proliferation of atherosclerosis. Professors Kamm and Shapiro studied the fluid mechanics of oscillatory flow in compliant tubes with application to methods for external cardiac assist, and continued research on the flow of aqueous humor in the eye in order to understand and diagnose, as well as treat or prevent glaucoma.

The most exciting development in the area this year was the completion in June of the Eric P. and Evelyn E. Newman Human Mechanics and Rehabilitation Laboratory through major reconstruction of space on the first floor of Building 3, formerly occupied by the Engineering Projects Laboratory. This Laboratory, developed under the leadership of Professor Robert Mann, Whitaker Professor of Biomedical Engineering, provides internationally unique facilities for real-time determination of the position of individual body segments and the dynamic joint loading during normal and pathological human movement. The Laboratory also provides prosthesis simulation capability for amputees and for mobility aids for the blind, as well as expanded testing capability related to studies of synovial joints (especially the human hip). As soon as needed additional office space can be acquired in the main building complex, the MIT Sensory Aids Evaluation and Development Center (now located in Building 31) will be integrated into the new Laboratory. This Center, directed by Professor Rowell and Principal Research Scientist Michael J. Rosen, is currently working on mobility and communication aids for the blind, devices for suppression of muscular tremor and vocal stutter, and the development of communication methods and environmental control systems for the non-verbal motor impaired. Several systems are in commercial production and in use by individuals, hospitals, and industrial organizations.

The new Laboratory provides outstanding experimental and computational support for the research of Professors Flowers and Neville Hogan, as well as Professors Mann and Rowell. The Department is proud of this premier new facility and is grateful to the Newmans for making it possible.

In the area of Manufacturing and Processing, research continued to grow both in volume and in scope. A wide range of activities in materials processing and manufacturing takes place in the Laboratory for Manufacturing and Productivity (LMP). In addition to the highly successful MIT-Industry Polymer Processing Program, programs are under way in automatic welding, the use of geothermal energy in industrial applications, and manufacturing axiomatics. Under Professor Stanley Backer, the Flexible Materials Program concentrates on generic issues that underlie the physical behavior and processing characteristics of flexible materials such as fibers, apparel, textiles, paper, and footwear. The Machine Dynamics Program, directed by Professor Richard H. Lyon in collaboration with Professor Seering, is concerned with the design, optimization, monitoring and fault diagnosis of high performance machines and mechanisms. This is a joint effort between the LMP and the Acoustics and Vibration Laboratory. A new inter-departmental effort, the Manufacturing Resources Program aims at innovative design of manufacturing processes in order to conserve energy, materials, and human resources. The program will also include manufacturing policy and the social aspects of manufacturing. This year, additional space was acquired in the basement of Building 35 which has been refurbished to accommodate new polymer processing machinery and provide some of the needed expansion space for the LMP. A major fund-raising effort has been planned to finance further expansion and modernization of the Laboratory.

Professor Williams continued his work in the non-destructive evaluation of composites by monitoring the acoustic emissions resulting from deformation, and of fiberglass boat hulls by thermal testing and the use of liquid crystals.

In the area of Computer-Aided Design and Computer-Aided Manufacturing (CAD/CAM), Professors Gossard and David E. Hardt continued development of computer controlled metal forming, including innovative techniques for brake- and die-forming. A major US manufacturer of brake-forming machines has provided a servo-controlled machine and is supporting work aimed at implementing real-time control of sheet metal bending on this company's products. Professor Gossard also continued his research on automatic drafting and on personal computer systems for teaching design.

In the field of Energy and Environment, the Department's initiatives in mining, fracturing, and recovery of oil from shale have led to the planning of a new Laboratory for Resource Extraction to be run jointly with the Department of Civil Engineering. The new facility, when completed, will provide major new experimental capabilities to support research in the basic properties and behavior of porous and geological materials (rock, coal, shale, etc.), and development of mining and oil recovery systems that have improved productivity and safety. Professors Thomas P. Bligh, Cleary, and Peterson are joining with Professors Jerome J. Connor, Jr., Herbert H. Einstein, and Daniele Veneziano of Civil Engineering in planning this new Laboratory in space to be provided by the two departments.

The Department also initiated a new program focused on energy conservation under the leadership of Dr. Glicksman. A one-day workshop, planned with the assistance of Senior Lecturers John P. Appleton and George N. Hatsopoulos and Professor Elias P. Gyftopoulos, was held at the MIT Endicott House in January which identified several promising areas for new MIT research: separation processes, heat pumps for industrial processes, cogeneration and combustion engines capable of using waste products and other low-grade fuels. Dr. Glicksman developed research on insulation and energy conservation in buildings jointly with Professor Douglas E. Mahone of the Department of Architecture, and Professor Bligh continued work on free energy ice air-conditioning and energy conservation by subsurface construction. During the next two years, the Department hopes to expand these activities into a major program on energy conservation in industrial and commercial systems.

Professors Smith and Michael E. Crawford, together with Professor James L. Kirtley, Jr., of the Department of Electrical Engineering, continued the cooperative effort between the Department's Cryogenics Laboratory and the Electric Power Systems Laboratory to demonstrate a 10 megawatt superconducting generator. A new building to house this major experiment has been completed on Albany Street and the generator, driven by an aircraft gas turbine, will be undergoing preliminary tests next year.

The Sloan Automotive Laboratory, directed by Professor Heywood and Dr. Joe M. Rife expanded its research in the area of diesel as well as advanced spark ignition engines. As a result of an

interdepartmental study on new opportunities for research in automotive technology at MIT, a major Automotive Performance Program has been proposed which will have its base at the Sloan Laboratory and will include such areas as combustion, tribology, engine and system control, transmission efficiency, aerodynamics, diagnostic instrumentation, vehicle dynamics, and noise and vibration. This Program will involve the Energy Laboratory, the Departments of Aeronautics and Astronautics, Chemical Engineering, Electrical Engineering and Computer Science, and Mechanical Engineering as well as the Laboratory for Information and Decision Systems and the Electric Power Systems Laboratory. A plan for facilities and space needs and a series of coordinated research proposals are currently being prepared for action during the 1980-81 academic year.

Activity in Systems, Including Transportation grew in scope in the areas of man-machine systems, rail vehicle dynamics and automotive technology. The Man-Machine Systems Laboratory, directed by Professor Sheridan initiated a study with the Draper Laboratory to design computer aids for human operators of nuclear plants. Work in supervisory control of undersea teleoperators continued, including the design of a new laboratory teleoperator and a joint effort with the Naval Ocean Systems Center in San Diego, to demonstrate a free swimming teleoperator equipped with a manipulator. A research effort in combined human-computer searches of large data bases was also initiated.

The Vehicle Dynamics Laboratory, directed by Professors Hedrick and Wormley continued to expand research in high-performance rail freight and passenger vehicles under sponsorship of the US Department of Transportation and the Association of American Railroads. A design handbook for passenger vehicle truck design was completed and the work entered a technology transfer phase through an arrangement with a major US car manufacturer. Research initiated last year by Professors Houpt, Heywood, and Wormley, Dr. Rife, and Professor Michael Athans of the Laboratory for Information and Decision Systems in electronic control of internal combustion engines, gained momentum through a junior faculty grant to Professor Houpt from a major automobile manufacturer.

FACULTY AND STAFF

Size and Composition

The dramatic increases in enrollment, and therefore of teaching load, in the Department during the past several years have placed heavy demands on the faculty and detracted significantly from the Department's ability to undertake curriculum and text development and to initiate new research which would lead to future shifts in research emphasis. During the past two academic years, however, some relief has been obtained through increases in the Department's general budget and School of Engineering efforts to attract external funding for junior faculty. Thus, since 1976-77, the number of assistant professors has increased from nine to 17 and the total regular faculty from 49 to 58. In 1979-80, the Department had 29 professors, 12 associate, and 17 assistant professors, as well as one adjunct professor. Nevertheless, at the end of 1978-79, the Department still had the lowest ratio of total budget allocated to credit units taught (\$39.60) at the Institute. Owing to stabilization of enrollment and the budget increases, this work load indicator is expected to improve (increase) when Department profile data for 1979-80 is available this fall. A steady-state goal for faculty size for the next few years has been set at 60, requiring the new addition of two more people.

Despite continued aggressive affirmative action policies, the distribution of women and minorities on the faculty remained substantially unchanged. The faculty includes three orientals, one black, and two women. Among the 69 adjunct teaching and research staff members, there are five orientals and five women. Of the seven administrative and exempt staff, five are women and of 32 support staff, all are women with no minorities represented. We still retain three blacks among our 19 hourly union employees, and of four technical exempt employees, one is an oriental.

Notable Accomplishments and Awards

Professor Paynter was presented the Rufus L. Oldenburger Medal by the Council of the American Society of Mechanical Engineers. This award, which is the highest honor the Society confers for professional accomplishments in the field of automatic control, cited Professor Paynter for "his creative accomplishments in all aspects of dynamic systems theory and practice..., his inspiring example to students and colleagues, and his supreme enthusiasm."

Professor Richardson, Department Head, was elected to the National Academy of Engineering for "leadership in transportation research and contributions to systems dynamics education in mechanical engineering."

Professor Emeritus and Senior Lecturer Jacob P. Den Hartog was awarded the American Society of Mechanical Engineers (ASME) Medal by the Council of the Society for his lifelong work in vibration. This is the highest honor the Society confers for "eminently distinguished engineering achievement."

Professor Rabinowicz was named a Fellow of the American Society of Lubrication Engineers.

Professor Peter W. Huber was selected by the Engineering School as the third holder of the Carl Richard Soderberg Associate Professorship in Power Engineering for a two-year period. Associate Professor Ritchie won the Class of 1922 Career Development Professorship based on his professional accomplishments and contributions to engineering education at MIT.

Professor Abouseif, who joined the Department's Thermal and Fluid Sciences Division this year, was a recipient of the General Electric Foundation Young Faculty Grant Award for 1979-80.

Professor Mikić won a Graduate Student Council Award for Outstanding Graduate Teaching. The award is granted for "effective and dedicated teaching of graduate-level courses."

Natalie D. Speckmann, Administrator, was the first recipient of the new James Holt Staff Service Award, established in memory of Professor Holt who served as Department Executive Officer for 16 years prior to his retirement in 1962. Miss Speckmann was recognized "for sustained and dedicated service to the Department and its people at all levels."

Professors James A. Fay and James C. Keck spent sabbatical leaves as Overseas Fellows at Cambridge University, England.

Professor Toong served as Visiting Professor at the Shanghai Jiaotong University, Shanghai, and gave invited lectures at the Institute of Mechanics and the Academia Sinica, both in the People's Republic of China.

Professor Wilson served as Visiting Scholar at the University of Nebraska at Lincoln, and gave a series of seminars on energy and environment.

Professor Yannas spent a sabbatical term at the National Technical University in Athens, Greece teaching and advising the university in the field of polymer science and engineering.

New Faculty

Two new assistant professors joined the Thermal and Fluid Sciences Division. Dr. Abouseif continued his doctoral research on combustion instability and collaborated with the Sloan Laboratory staff on automotive engine combustion research. Dr. Maher El-Masri contributed to ongoing research in water-cooled gas turbine engines and will help strengthen the Department's efforts in the field of energy conservation.

In the Mechanics and Materials Division, four assistant professors were appointed, three of whom will be associated with the Laboratory for Manufacturing and Productivity. Dr. Lewis Erwin, DuPont Assistant Professor of Mechanical Engineering, is associated with the MIT-Industry Polymer Processing Program. Dr. Hardt works in the area of computer-aided manufacturing, and Dr. Bruce M. Kramer has initiated research in the areas of material removal and other aspects of

manufacturing. Dr. Bassani has been collaborating with Professors McClintock and Argon in the area of fracture mechanics.

Dr. Neville Hogan was appointed assistant professor in the Systems and Design Division. He continued his postdoctoral work in the study of human movement and prosthetics, both in the Department and in collaboration with the Department of Psychology.

Visiting Faculty

Dr. Friedrich Prinz, of the University of Vienna, who was also a visitor in 1977, was a visiting associate professor working in the field of recovery in creep and plastic deformation and gave special lectures and an undergraduate seminar.

Dr. Julius Solnés, of the University of Iceland, was a visiting professor. He continued his work in stochastic load processes on structures with Professor Crandall. In addition, he taught 2.061 Random Vibration.

Dr. George S. Springer, a visiting professor who is a former faculty member in the Department and is now with the University of Michigan, spent his sabbatical year working with members of the Sloan Automotive Laboratory and the Combustion Group. He also taught the undergraduate course, 2.40 Thermodynamics.

Dr. Merrill L. Ebner, chairman of the Manufacturing Engineering Department at Boston University, spent the spring term as visiting professor in the Laboratory for Manufacturing and Productivity where he wrote an undergraduate text in manufacturing and design and gave graduate seminars.

Resignations

The resignations of Professor Günther Werner and Professors Crawford and Bassani were accepted with regret. Dr. Werner has been appointed to the faculty of the Production Engineering Department of the University of Bremen, Germany. Dr. Crawford will join the faculty at the University of Texas at Austin. Dr. Bassani has been appointed to the faculty of the Mechanical Engineering and Applied Mechanics Department at the University of Pennsylvania.

HERBERT H. RICHARDSON

Department of Nuclear Engineering

During the past year much has happened that affects the nuclear industry. The serious nuclear accident at Three Mile Island has caused considerable concern about nuclear power. At the same time the problems in the Middle East have continued to demonstrate the vulnerability of the industrialized world to events in that area. This has intensified the determination to develop substitutes for oil. Following his review of the Report of the President's Commission on the Accident at Three Mile Island, the President has stated the necessity of using nuclear power as part of the solution to the energy problem. Nevertheless, the electric industry is apprehensive about ordering new nuclear power plants until the licensing process is more certain.

There are numerous studies and investigations of the Three Mile Island accident, not all of which are yet complete. It seems clear that until all of these reports are finished, and the Nuclear Regulatory Commission has responded to them, a cloud of uncertainty will hang over the licensing process. There are hopeful signs, however. Many of the improvements suggested by the President's Commission on the Accident at Three Mile Island have already been implemented. If this situation remains true, then it seems possible that the issue can be resolved within 12 to 18 months. Hopefully the whole licensing process will become clearer and better defined as part of this effort. If so then it may produce a climate in which new plants will once again be ordered.

Despite the fall-off in nuclear orders, the demand for trained nuclear engineers continues to grow. The best projections available indicate that about 1,500 S.B. graduates and 500 to 800 advanced degree (S.M. and Ph.D.) graduates per year will be needed to support the nuclear industry. These numbers do not include the needs of the growing research and development programs in fusion. Today, the total United States supply of S.B. graduates is about 600 and the number of advanced Nuclear Engineering degrees being awarded is about 650. Currently the shortfalls are made up by hiring engineers from other disciplines who have had some nuclear courses. Because the demands are not expected to decrease for the next decade it seems likely that there will continue to be a shortage of trained nuclear engineers for some time.

ACADEMIC PROGRAM

During the 1979-80 academic year the number of well-qualified applicants for graduate training continued to exceed available openings. There was a modest increase (about nine percent) in the total number of applicants from the previous academic year. We are continuing to see an increasing number of applicants with interest in the fusion area. Graduate enrollment in 1979-80 was 166 students. The Department awarded 67 advanced degrees including 19 Doctorates, 8 Nuclear Engineer, and 40 Masters of Science. This represents approximately 10 percent of the advanced degrees in Nuclear Engineering awarded nationally.

The Department received confirmation of the accreditation of its Bachelor of Science program by the Accreditation Board for Engineering and Technology. In June 1980 ten freshmen chose nuclear engineering as their major field of study. The total undergraduate enrollment during 1979-80 was 18 sophomores, 7 juniors, and 14 seniors.

During the past year the academic program has undergone only modest change. The Department is planning to expand its offerings in more broadly based energy courses. Professor Richard Lester has proposed a course on nuclear energy policy analysis which will be offered in spring 1981. This course will analyze interactions between technological developments and institutions in the nuclear fuel cycle, and explore the consequences of these interactions for nuclear power policy. Professor David Rose contributed to the development of a new course entitled, "The Finite Earth: Agendas for a More Just, Sustainable and Participatory Society," which is offered jointly with the Departments of Political Science, Humanities, and Architecture. Depending upon the response to these new courses, the Department may continue to expand its curriculum in this area. In the fusion area a new course on magnetohydrodynamic (MHD) theory was developed by Professor Jeffrey Friedberg. This is the first course on MHD theory offered at the Institute and it is designed to meet the growing interest and need in the fusion area.

The Engineering Internship Program, which offers undergraduates the opportunity to have on-the-job experience as part of their overall education, has been successful since it was initiated two years ago. A total of six students -- three juniors and three seniors -- are now in the program. We are continuing to try to increase the number of participating companies to accommodate the growing interest of students in this program.

The continued high level of funded research has enabled the Department to provide research support for about 60 students; in addition, another 53 are supported by a variety of teaching assistantships and fellowships.

During the summer of 1979 the Department offered a Special Summer Program on Nuclear Power Reactor Safety, directed by Professors Neil Todreas and Norman Rasmussen. This program is an important way of establishing contacts between the Department and the various parts of the nuclear industry, as well as a means of providing added income. The 170 registrants in this program accounted for 10 percent of the registrants in all MIT Special Summer Programs. In June 1980 a one-week Summer Session Program entitled "Man-Machine Interfacing in Nuclear Power and Industrial Process Control" was offered as a joint department course involving Professor Thomas Sheridan from Mechanical Engineering and Professor David Lanning from Nuclear Engineering. The subject is timely with respect to new requirements and innovations proposed for improvements in nuclear power plant control rooms. The Program was well attended, having a registration of 93 people from many industries and countries throughout the world.

In response to concern regarding the quality of press coverage of nuclear power-related issues, a special seminar, "Nuclear Power: Challenge for Journalists," was offered in October 1979. The seminar was directed by Professor Michael Golay and was staffed primarily by Nuclear Engineering faculty. It was offered under the auspices of the Seminar Office of the Center for Advanced Engineering Studies. The goal of the seminar was to offer an intensive short course on nuclear power issues in a fashion which is as objective as possible, so that reporting of future nuclear power stories could be characterized more by interpretation and independent understanding than has been the case in the past. It was carefully structured to avoid social advocacy presentations. The seminar, which was self-supporting, attracted approximately 40 participants from the United States, Canada, Japan, and Denmark.

Student Awards

We are proud to report that the Department's student chapter of the American Nuclear Society (ANS) won the 1980 Glasstone Award. This award is given to the most outstanding student chapter in the ANS.

The ANS student chapter also received the second place award for public relations. This award recognizes the many contributions that our students have made in providing information on nuclear power to the public.

Two of our doctoral candidates won first prize for best paper in their session at the March 1980 Student ANS Conference held at the University of Tennessee. Anthony O. Adegbulugbe won first prize for his paper in the session on thermal ratcheting in fusion reactor first walls. Paul Gierszewski won first prize for best paper in the general category. His paper was entitled "Natural Circulation in Fusion Reactor Blankets."

Mohammed (Pirooz) Sharafi, a doctoral candidate in our Department, won the third annual Institute for Nuclear Materials Management (INMM) student paper award (\$500 plus honorary membership) for his engineer's thesis on a CIVEX reprocessing technique. He presented a paper at the 1980 National INMM meeting at Palm Beach where he was honored as the award winner.

Richard P. Burke, a junior in our Department, received a citation and a \$1,000 scholarship as winner of the ANS Charles T. Chave Award. The award is given for scholastic excellence and leadership.

RESEARCH

The total dollar volume of research supervised by the Nuclear Engineering faculty during fiscal year 1979 was approximately \$2.3 million. This represents an increase of \$248,000, or approximately 12 percent over the comparable fiscal year 1978 figure of \$2.1 million.

Fiscal 1979 saw a net reduction in the research volume actually assigned to the Department of \$325,000 -- down from \$1,382,000 in fiscal 1978 to \$1,057,000. Approximately \$275,000 of funding from the Department of Energy and the National Science Foundation (NSF) was administratively transferred to the MIT Plasma Fusion Center (\$265,000) and the Research Laboratory of Electronics (\$10,000). Another \$110,000 of research sponsored by the Department of Health, Education and Welfare DHEW (\$80,000), Department of Defense (\$25,000) and NSF (\$5,000) was brought to a conclusion. These reductions in volume were offset, in part, by a \$60,000 increase in the combined support received from the Nuclear Regulatory Commission, national laboratories, and private industry.

Approximately 35 percent of the research conducted within the Department of Nuclear Engineering in fiscal 1979 was sponsored by non-governmental sources, chiefly the Electric Power Research Institute and private utilities. Investigations in areas other than plasma fusion continued to be funded by the US Department of Energy in an amount approaching 30 percent of the Department's total research volume. Research sponsored by the National Science Foundation in fiscal 1979 was 12 percent of the Department total and the Nuclear Regulatory Commission funding represented almost 9 percent of the Department's research volume.

The Department continued to receive fellowship support from the General Electric Foundation, Northeast Utilities, and the proceeds from the Theos J. Thompson Memorial Fund. Department spending in this area increased by approximately 45 percent in fiscal 1979 -- up from \$24,600 to \$35,600.

The research work in the area of fusion technology and plasma physics continues strong. Professors Lawrence Lidsky and Peter Politzer continue their work in various aspects of fusion technology. Professor Thomas Dupree continues his work in plasma turbulence. Professor Freidberg has been working in the area of plasma stability using MHD theory; while Professor Kim Molvig's work is in the area of TOKAMAK theory, where his work on energy confinement is receiving considerable attention. Professor Mujid Kazimi continues his studies of fusion reactor safety.

In the area of reactor physics Professor Allan Henry has continued his work on the dynamic behavior of light-water moderated reactors. This research is sponsored by the Electric Power Research Institute (EPRI). Professor Michael Driscoll has continued his work on the design of fast reactor blankets.

The Department continues its broad activities in the area of thermal hydraulics and fluid flow. Professors Todreas, Lanning, Kazimi, Golay, and John Meyer have contributed individually and jointly to studies of sodium boiling in Liquid Metals Fast Breeder Reactor (LMFBR), Pressurized Water Reactor (PWR) steam generator modeling, two-phase flow in light water reactors, cooling tower fluid flow, and thermal problems in fusion devices. This last effort on divertor design for TOKAMAK fusion machines is an excellent example of how the broad engineering experiences gained with fission technology have many direct applications to the engineering design of fusion machines.

The accident at Three Mile Island has led to an increase of the Department's research activities in the area of reactor safety. Professor Lanning has been working jointly with the Draper Laboratory on a project to improve the man-machine interface -- especially in the control room design. Several of the projects being pursued by the thermal hydraulics group mentioned above deal with specific safety-related questions such as the modeling of the steam generator and the understanding of sodium boiling in LMFBRs. As noted above, Professor Kazimi is finding his broad experience with LMFBR safety particularly useful in his studies of fusion reactor safety. Professor Rasmussen and Dr. Carolyn Heising-Goodman have been doing reliability studies on a variety of nuclear power plant systems to better understand the relative importance to overall safety of various plant systems.

Professors Driscoll and Lester continued the Department work in the area of nuclear fuel cycles. Professor Lester's work has been in the areas of proliferation, enrichment policy, and nuclear waste disposal; while Professor Driscoll's work has been on the improvement of uranium utilization and the recovery of uranium from seawater.

Departmental activity in the important area of nuclear materials problems increased considerably during the past year. Professor Meyer has investigated structural problems in nuclear fuel cladding. Professors Otto Harling and Kenneth Russell have a major effort under way, studying radiation damage effects that may be expected in a fusion reactor, particularly helium formation in the first wall.

The Department has a significant involvement in the area of broad energy issues which is led by Professor Rose in cooperation with Professor Lester and Dr. Marvin Miller. The goal of this work is to develop the basic data and methods of analysis to improve the optimization of a national energy strategy. These studies deal with a wide range of issues, from realistic conservation goals to the characteristics of various energy production technologies. We believe such studies are essential for better defining the optimal role of nuclear energy as well as other energy forms. Professor Elias Gyftopoulos has continued his work in the area of energy conservation through his work on the thermodynamics of industrialized processes.

Professors Sow-Hsin Chen and Sidney Yip lead the Department's efforts in the area of applied radiation physics. Professor Chen, with support from NATO and the National Institutes of Health (NIH), is organizing an Advanced Study Institute to take place next year in the area of scattering techniques applied to supramolecules and non-equilibrium systems. Professor Yip is carrying out theoretical studies on the dynamics of dense fluids. In the area of nuclear medicine Professor Gordon Brownell continues his developments in the area of computed tomography for the diagnosis of disease. In this work, his laboratory at the Massachusetts General Hospital developed a tomographic positron camera that offers considerable promise as a diagnostic procedure.

FACULTY

The Department added three assistant professors to the faculty, bringing the current number of Nuclear Engineering faculty to 23. Professor Lester joined the Department as an Esther and Harold E. Edgerton Assistant Professor of Nuclear Engineering. Professor Lester will strengthen our program in the areas of international nuclear policy and in nuclear chemical engineering.

Professor I-Wei Chen has accepted a joint appointment as an Assistant Professor in the Department of Nuclear Engineering and the Department of Materials Science and Engineering. Professor Chen has done outstanding work in the area of creep. He will continue in this general area, applying his knowledge of creep to problems in both fusion and fission reactors.

Professor Alan C. Nelson will be joining the Department as an Assistant Professor in the fall of 1980 with a joint appointment in the Department of Nuclear Engineering and the Harvard-MIT Division of Health Sciences and Technology. Professor Nelson will strengthen the Department in the area of biomedical applications of nuclear radiation.

The Department is pleased to report that Professor Driscoll was promoted to Professor of Nuclear Engineering.

Professor Golay has been on sabbatical leave at Electricite de France since January 1980 and will return to the Department at the end of 1980.

Professor Ralph Bennett has resigned to take a position in industry.

Faculty Activities

Departmental faculty members continue to be active in both MIT non-departmental activities and in a wide variety of activities outside of MIT, including professional societies, government, and industry.

Professor Rose played a key role in organizing the World Council of Churches Conference on Faith, Science, and the Future, held at MIT during the summer of 1979. This successful conference was attended by about 400 people -- engineers, scientists, church delegates, public administrators, and students from all over the world. Professor Chen was invited by Academia Sinica of The People's Republic of China to visit the Physics and Nuclear Energy Research Laboratories in Peking and Shanghai. During his one-month stay in May and June, he gave eight lectures on neutron physics. Professor Driscoll completed his term as chairman of the Reactor Physics Division of the American Nuclear Society. He continues as faculty chairman of the MIT Undergraduate Seminar Program. He also was recently appointed to the Institute's Committee on Educational Policy as the representative of the School of Engineering, and to the Committee on the Humanities, Arts, and Social Sciences. Professor Golay is currently on sabbatical leave at the Laboratoire National D'Hdraulique near Paris. He is also chairman of the Environmental Sciences Division of the ANS and until recently served as chairman of the Institute's Environmental Engineer Degree Program. Professor Gyftopoulos continues as chairman of the National Energy Council of Greece. Professor Henry continues to serve on the Institute's Committee on Graduate School Policy. He is a member of the Journal Advisory Board of the ANS and serves as an advisor to the Nuclear Regulatory Commission. Professor Kazimi is a member of the Heat Transfer Committee and is chairman-designate of the Committee on Nucleonics Heat Transfer of the American

Institute of Chemical Engineers (AIChE). He also serves as director of the Northeastern section of the ANS. During the past year, Professor Kazimi has participated in the International study of INTOR Fusion Reactor. Professor Lidsky serves as editor of the new *Journal of Fusion Energy*. Professor Politzer has taken a one-year leave of absence to serve full time on the Plasma Fusion Center's research staff. Professor Rose has for the past four years been a member of the National Academy of Sciences Committee on Nuclear and Alternative Energy Systems. Professor Russell serves as chairman of the Institute's Student Activities Development Board and as chairman of the Heat Treatment Committee of Metallurgy for the AIChE. Professor Todreas serves as vice chairman of the Technical Working Group on Thermal Hydraulics for the American Nuclear Society and chairman of the Heat Transfer Division, Honors and Awards Committee of the American Society of Mechanical Engineers (ASME). He also is on the editorial board of the thermal design area of the *Journal of Nuclear Engineering and Design*. Professor Rasmussen was appointed to the Utility Scientific Advisory Committee organized by EPRI to review the Three Mile Island accident and make recommendations to the utility industry. He was appointed a senior consultant to the Defense Science Board. He continues to serve as chairman of the MIT Reactor Safeguards Committee on which Professors Driscoll, Lanning, and Harling also serve. He serves as chairman of the EG&G Idaho National Engineering Laboratory Scientific Review Committee and also as chairman of the Fusion Safety Review Committee at that laboratory. He is a member of the Board of Directors of the ANS.

Honors and Awards

Several of the Department faculty were recognized with honors during the past year. Professor Rose presented the James R. Killian, Jr. award lectures this spring. This award, made annually by the Institute on the advice of a faculty selection committee, is given to the faculty member who, in the opinion of the selection committee, has made the greatest contribution toward the Institute's overall excellence. Professor Yip was a recipient of a US Senior Scientist Award given by the Alexander von Humboldt Foundation. Professor Todreas received the Outstanding Teacher Award of the MIT student chapter of the American Nuclear Society. Professor Manson Benedict was presented the Henry DeWolf Smyth Nuclear Statesman Award by the ANS and the Atomic Industrial Forum. This award recognizes outstanding service in developing and guiding the uses of atomic energy in constructive channels. Professor Henry received the Glen Murphy Award of the American Society of Engineering Education for Outstanding Teaching in Nuclear Engineering. Professor Rasmussen received an honorary doctorate from the Catholic University of Leuven.

NORMAN CARL RASMUSSEN

Department of Ocean Engineering

An endowed undergraduate academic prize has been established in memory of Robert Bruce Wallace, Class of 1898, an alumnus of the Department. The prize of \$10,000 is to be awarded annually to an undergraduate student, on the basis of academic excellence and promise for professional leadership in ocean engineering. The first recipient, James Hancock, Class of 1980, will receive the prize at an award ceremony at the beginning of the next academic year. He is expected to receive his S.B. and an S.M. in June 1981.

We are pleased to report continued support of Kawasaki Heavy Industries for the Kawasaki Research Fund, established to enhance welding research at MIT. The Kawasaki Research Fund has been instrumental in furthering the welding program of the Department, providing for specialized equipment, and visits of welding engineers from abroad.

The Department is also pleased to report that an endowed professorship in international shipping is likely to be established in 1980-81. A benefactor has made a commitment towards funding such a chair, and at present a search is under way for the incumbent. The Program envisioned would have, in addition to a chair, a research fund for which additional contributions are being sought.

These developments are very significant. They do much to ensure the vitality of the Department's programs and the quality of its student body.

ACADEMIC AND RESEARCH HIGHLIGHTS

The Department's curricula are constantly revised in order to maintain relevance to present and future needs of both the student body and society. During the year, four graduate subjects were developed: "Control Theory Applications," "Engineering Systems Design," "Wave Loads and Motions of Marine Structures," and "Fisheries Management." Two interdepartmental graduate subjects were developed in conjunction with the faculty of other departments: "Economics of Ocean Transportation" and "Quantitative Models in Transportation Planning."

Two undergraduate subjects were substantially revised. These are "Introduction to Marine Applied Mechanics" and "Marine Applied Mechanics."

During the Independent Activities Period, 19 undergraduates went to sea on the schooner *Westward*, a training ship of the Sea Educational Association. Professor and Mrs. A.D. Carmichael of the Department provided educational and social foci, respectively. Ocean engineering experiments included aerodynamic behavior of the sails, resistance of the hull, performance of the ship under diesel power, properties of the propeller both in propulsion and as a potential source of generator power when sailing, and ocean temperature gradients for thermal energy conversion.

A plume tank, just completed in the Department, is a facility for studying single phase or mixed plumes of oil, water, and gas. This is to be used principally by Professor Jerome H. Milgram and colleagues for studying the fluid mechanical structure of subsea blowouts of oil and gas wells, and for studying concepts for subsurface oil collectors to be used after such accidents. The plume tank is located adjacent to the precision flume and the variable pressure water tunnel, so that they can share common support equipment and instruments.

Professor J.T. Kildow and several faculty colleagues are studying decision making relevant to Boston Harbor, with special emphasis on the many governmental entities with partial jurisdiction, on various strategies for economic development, and on citizen groups that communicate more general and sometimes contradictory public needs. A better understood and more highly responsive management system for Boston Harbor is the objective of this research.

An expedition to the Arctic Ocean, under the leadership of Professors A.B. Baggeroer and Ira Dyer, was successfully mounted and completed. Several other teaching and research institutions participated with MIT. Information was obtained on the nature and type of bottom sediments, and the backscattering of acoustic signals from the continental slopes, as two examples of the many research objectives. Camps were established and maintained on the Arctic ice with the use of fixed-wing aircraft and helicopters.

FACULTY

Professor Ronald W. Yeung was awarded permanent tenure which will be effective July 1, 1980.

Professor Dyer was on sabbatical leave this year as Visiting Fellow, Emmanuel College and Visitor, Engineering Department, Cambridge University, England.

Professor Henry S. Marcus participated in teaching and research at Harvard Business School during his sabbatical.

The resignation of Professor Philip Mandel was accepted with regret. As a step in early retirement, he has accepted a position at the Naval Ship Research and Development Center in Carderock, Maryland.

Visiting Faculty and Staff

Visiting Professor Peter Atkinson of Kings College, Newcastle, England has assisted in the teaching of the Department's design curriculum, as well as in research on ship design with Professor Chryssostomidis.

Visiting Professor Kiyohida Terai (Kawasaki Heavy Industries and Visiting Lecturer at the University of Tokyo, Nagoya University, and Tohoku University) has continued to assist Professor Koichi Masubuchi in his welding research, as has Visiting Engineer Akihiko Imakita of Mitsui Engineering & Shipbuilding Co. of Japan.

Visiting Professor Tarik Sabuncu, head of the Ship Hydrodynamics Division of the Faculty of Naval Architecture at the Technical University of Istanbul, remained with the Department through May 1980, and conducted research on practical schemes for implementing wave resistance optimization in ship design.

The Department hosted two Visiting Scientists from Poland; Ludwik J. Kondratowicz worked with Professor Harilaos Psaraffis on an oil spill study, and Zofia Sawiczewska performed research on shipping conferences and labor efficiency with Professor Ernst Frankel.

Honors and Awards

Professor Justin E. Kerwin was awarded the Captain Joseph H. Linnard Prize for 1979 by the Society of Naval Architects and Marine Engineers; Professor Masubuchi received the District Meritorious Certificate award from the American Welding Society; and Professor Harilaos H. Psaraffis won first prize in a contest on transportation-related Ph.D. dissertations of the Transportation Science Section of the Operations Research Society of America.

New Books

"Analysis of Welded Structures -- Residual Stresses and Distortion and Their Consequences" by Professor Masubuchi is to be published by Pergamon Press; and *Deep Sea Mining*, edited by Professor Judith Kildow, was published by the MIT Press.

Public Service

William Baker has provided curatorial services for the City of Boston in connection with the City Hall exhibition: "Gateway to the Sea -- 350 Years of Boston Harbor." He also participated in three television shows dealing with various aspects of maritime history.

Professors Kerwin and J. Nicholas Newman are advisors to the US Yacht Racing Union on continuing development and application of the Measurement Handicap System.

In two separate television appearances, Professor Kildow described opportunities and complexities in the development and management of Boston Harbor.

Professor Jerome Milgram prepared and presented a testimony entitled "The Campeche Bay, Mexico Oil Spill and Its Implications for Oil and Gas Development on the US Outer Continental Shelf," for the US Senate Committee on Commerce, Science, and Transportation, and the Committee on Energy and Natural Resources.

International Activities

Mr. Baker presided at the annual meeting of the North American Society for Oceanic History held in Halifax, Nova Scotia. He also presided at one working session of the Third Reunion for the History of Nautical Science and Hydrography in London.

Professor A. Douglas Carmichael is chairman of the Computer-Aided Design Committee and International Cooperation on Marine Engineering Systems (ICMES). He is a member of the Committee of Scientists, Office of Energy of Puerto Rico, and visited India to discuss invention and innovation.

Professor Dyer presented "Arctic Exploration with Sound Waves" before the Cambridge Philosophical Society, England, as their featured lecturer.

Professor Kerwin is a member of the cooperative exchange of propeller research results and computer programs, which has organizations in Norway, Sweden, West Germany, and Canada.

Talks were given by Professor Kildow in Madrid and Santiago, Spain, on "Aquaculture and Chemical Effluents."

Professor Masubuchi is vice chairman of Commission X (Residual Stresses, Stress Relieving, and Brittle Fracture) of the International Institute of Welding. He visited the Republic of Korea on a research project entitled "Strategies and Courses of Action for Technology Development in the Republic of Korea" conducted at MIT's Center for Policy Alternatives, for the World Bank.

Professor Newman has delivered papers at the symposium on "Advances in Marine Technology," Trondheim, Norway and at the symposium on "Wave Energy Utilization" in Gothenberg. He lectured on ship motions at the Institute fur Schiffbau, Hamburg, West Germany.

Professor Psaraftis presented papers at the 10th International Symposium on Mathematical Programming, Montreal, Canada and the Fourth European Congress on Operations Research, Cambridge, England.

Professor Paul Xirochakis is a scientific reviewer for the Program of Technical Research for the government of Greece.

Professor Yeung is a member of the US-Japan Scientific Exchange program on Ship Motions in Shallow Water.

HART NAUTICAL MUSEUM

The Hart Nautical Museum received a 9-foot long, full hull, cased model of the Swedish-built tanker *Esso Yorkshire*. With this gift from Esso International, Inc. was a photograph album containing a record of the ship's launching festivities in 1963 and of most of the compartments on board.

Other gifts to the museum during the year included a 9" card compass, an 8½" pelorus, a collection of gouges and chisels, 15 plans for a Shipman (Boston) 3" x 4" steam launch engine drawn by a Canadian alumnus, and an important English brass frame sextant, circa 1770. The dividing mechanism employed in making this sextant's scale was so accurate that it was put to work again for the manufacture of sextants during World War I. Books were received from the Chesapeake Bay Maritime Museum; Time-Life Books, Inc.; Professor C. Fayette Taylor, Class of 1929; and the estate of S.G. Hardy of Hingham. Five books were added by purchase.

Museum plans, prints, and photographs were used in publications by the National Geographic Society; Time-Life Books, Inc.; the French Editions Maritimes and d'Outre-Mer; Professor C. Fayette Taylor; and Professor H.M. Irvine. Three prints of sea serpents were used by La Descent Productions, Inc., of Los Angeles for a TV documentary film. The Science Museum of Boston photographed the model of the Earl H. Potter for use in its special planetarium show "...And a Star to Steer Her By" in connection with Operation Sail 1980.

Contact is maintained with other maritime museums here and abroad through the International Congress of Maritime Museums and the Council of American Maritime Museums. Contact with maritime historians is primarily through the North American Society for Oceanic History which

held its 1980 meeting in Halifax in May; the curator's second term as president will end on December 31, 1980. Contact with the yachting world is maintained by the large number of telephone calls, letters, and visitors concerned with the repairing or building of yachts that were designed by the naval architects represented in the Museum's collections. The greatest activity this past year has been with the plans of William H. Hand, Jr., of New Bedford who was the subject of two articles in *WoodenBoat* magazine.

IRA DYER

Committee on Engineering Education

The Committee on Engineering Education (CEE), which was initially established in 1976, was reorganized this year and Professor James W. Mar became the new chairman. The members during the past academic year were: Professor A. Douglas Carmichael, Professor Lawrence B. Evans, Dean Kent F. Hansen, and Professors Frank A. McClintock, James K. Roberge, and Bernhardt J. Wuensch. Professor Wuensch has completed his term of service on the CEE. All the others, with the exception of Dean Hansen, were newly appointed.

The word "discovery" best characterizes the many discussions and activities of the CEE during the past year. We published one issue of the CEE Newsletter and held one Open Hearing in order to obtain ideas relative to engineering and human affairs from the faculty of the School of Engineering. I had expected the CEE to arrive at conclusions which would lead to recommendations for the School of Engineering. That this did not happen is a disappointment. The CEE grappled with many issues which will require more time before a consensus can be reached.

The projects, tasks, chores, and charges which came before the CEE and were discussed are listed as follows:

- | | |
|---|---|
| 1) Basic engineering courses | 8) School-Wide Electives |
| 2) Engineering and human affairs | 9) Engineering School and the College of Science, Technology, and Society |
| 3) Dual degree | 10) Measurement Laboratory subject |
| 4) Law-related subjects | 11) Energy brochure |
| 5) Writing program | 12) Area committees |
| 6) Undesignated degrees | 13) CORE requirements for degree |
| 7) "What is Engineering" freshman seminar | |

The School of Science appears to be receptive to suggestions for improvements and changes in the Math, Physics, and Chemistry Institute requirements. Dean Robert A. Alberty chairs a "CORE" committee and the CEE, as well as other constituencies of the Engineering School, are represented. The CEE believes this is an opportunity which should be acted upon.

I am most hopeful that the CEE during the coming year will be able to make positive recommendations on some selected issues.

JAMES W. MAR

Center for Advanced Engineering Study

The need for continual learning opportunities, especially in the engineering profession, continues to be recognized in the United States and throughout the world. The Center attempts to meet the need through three different kinds of offerings and a program of research and development to create new offerings.

The Advanced Study Program is now space-limited and must turn away qualified applicants. The Self-Study Program, based on videotaped courses, continues its spectacular growth; it now serves over 23,000 students per year and is the largest of its kind in the world. Our newest offering, the Program of Conferences, Seminars, and Short Courses, this year coordinated a number of meetings in a variety of technical areas, both on and off campus.

Our Research and Development Program also continues to grow. Projects PROCEED and TRANSMIT are supported by both government and industry. A feasibility study is being conducted to see if the PROCEED format can be applied to the budgetary process of the United States Government House Information Systems.

The Center also is conducting a Department of Energy-sponsored research project in complex thermoeconomic systems under the direction of Professors Myron Tribus and Yehia El-Sayed.

THE CENTER'S PROGRAMS

Advanced Study Program

The Advanced Study Program is an on-campus program that enables engineers and scientists to work in depth in technological areas of their choice. The program serves technical managers who wish to understand developments that bear directly on their problems, men and women who seek competence in depth at technological frontiers, and those who desire to strengthen their technological base. This year there were 74 fellows from 23 countries. The Advanced Study Program is directed by Dr. Paul Brown.

Fellows of the Program are affiliated with the Center for one or more terms. They may develop courses of study to meet their individual needs or may participate in specialized programs such as the Advanced Study Programs in Air Transportation or Education for Public Management. The entire offerings of MIT undergraduate and graduate subjects, seminars, and colloquia are available, and participation in ongoing research work may be carried out and self-study programs with informal tutorial assistance arranged.

The Programs coincide with the normal academic terms and academic year. Special weekly seminars are planned and conducted during the fall and spring terms especially for fellows of the Advanced Study Programs and the Education for Public Management Program. Each term, several special subjects of broad interdisciplinary interest are also offered within the Center for participants in the programs.

Before the fall term begins, participants in the Advanced Study Program may attend Calculus Revisited, an optional six-week review which provides an opportunity for strengthening mathematical skills before entering the mainstream of activities of the Center. This review is an intensive development of the first two years of a modern approach to calculus. Grades are recorded for all MIT subjects taken for credit. A certificate is awarded following satisfactory completion of a Program. Fellows also may apply for admission to the MIT Graduate School.

Self-Study Program

The Self-Study Program has produced over 700 videotapes to date. A production rate of 100 tapes per year has been planned for the next several years. Anticipated new subjects include: Microprocessors for Managers, Finite Elements, Management of Technology, Introduction to Analog and Digital Signal Processing, and Advanced Microprocessors Applications. Our research indicates that MIT is the largest producer of high-technology, video-based programming in the world.

The international component of the business is growing rapidly. Several South American universities and government agencies are adding Spanish soundtracks to our tapes. Under these arrangements, MIT retains all copyright and distribution rights. Further, we plan to produce the new Finite Elements course in both English and German. The market potential in German-speaking countries is very large.

Revenue in fiscal 1980 exceeded \$700,000, a new record. Established courses like Microprocessors, Modern Control Theory, and Digital Signal Processing continue to be utilized by industry worldwide. We project similar success for two recently developed courses: Corrosion Engineering and Electrochemistry.

The Conference, Seminar, and Short Course Program

The Seminar and Conference Office was established in 1977 to provide professional marketing and logistical support for the growing number of technical continuing education conferences, seminars, and non-credit short courses at MIT. While the majority of programs offered through the Seminar Office are sponsored by the School of Engineering, the Office is prepared to handle continuing education programs from any area of science and technology, and is designed to coordinate these programs on and off campus -- in the United States and elsewhere throughout the world. The Seminar Office has received the approval of both Engineering Council and Academic Council as a recognized office of continuing education at MIT.

Faculty members who wish to sponsor a non-credit short course or conference meet with the Director of the Seminar Office to discuss the program outline and financial considerations. Once a budget is approved, the Seminar Office obtains the necessary space approvals at the Institute and coordinates the specific needs of each meeting through a variety of support services including Campus Patrol, MIT dining, the Student Center, Physical Plant, MIT housing and outside facilities. A marketing plan is developed for each program which tailors the direct-mail campaign to the specific interest groups as identified by the sponsoring faculty member. The Seminar Office provides a comprehensive service, including the coordination of all related meeting publications, a registration office, professional aides to assist throughout the meeting, the organization of spouses' programs, field trips, and a follow-up marketing summary which is a valuable aid in the event the faculty member wishes to repeat the program at a later date.

A major goal of the Seminar Office is to make each continuing education program an enjoyable and positive educational experience for all sponsoring faculty members and program attendees. In working to attain this goal, the Office tries to relieve the sponsoring faculty member of the numerous pressures surrounding each program, while ensuring precise quality control in all areas of involvement. Members of the Seminar Office confer frequently with faculty members for periodic updates and consultation, but the bulk of the preparation for the program is removed from the faculty member. Likewise, the Office takes a special interest in the educational needs and well-being of attendees, and is available to help trouble-shoot any travel difficulties or special problems that might arise while attending a continuing education program.

The heavy demand for continuing education offerings has resulted in a growing number of programs at MIT. A few of the 1980 programs included: "Fusion Energy: Can We Have It? When?" sponsored by the Department of Nuclear Engineering; "Climate and Risk" sponsored by the Center for Advanced Engineering Study; "Macro-Engineering" sponsored by the School of Engineering; "Finite Elements" sponsored by the Department of Aeronautics and Astronautics; "Economic Regulations of Air Transport" sponsored by the Department of Aeronautics and Astronautics; "Nuclear Power: Challenge for Journalists II" sponsored by the Department of Nuclear Engineering; and "Stress Management" sponsored by the MIT Medical Department.

During 1979, over 19 foreign countries and 40 of the United States were represented at continuing education offerings from the Seminar Office. The 200 percent increase in requests for program information is an indication of the interest in continuing education meetings. Therefore, the number of program offerings is certain to increase substantially during 1981.

Project PROCEED

Project PROCEED (Program for Continuing Engineering Education) originated several years ago within a group of MIT professors, led by Professor Lawrence B. Evans of the Department of Chemical Engineering. It originally was intended to be an innovative approach to continuing engineering education by providing modular instruction so that busy engineers would not have to take an entire subject just to learn the parts that interested them. The Project was funded by the National Science Foundation (NSF) in 1975. Dr. Myron Tribus, Director of CAES, joined Professor Evans as co-director of the Project the same year he came to MIT. Professor Karen C. Cohen is now the director and principal investigator of the Project.

As the problems of continuing education were studied, it was decided that the approach should not only be modular, but also problem-oriented, in contrast with the discipline-oriented approach used for most undergraduate and graduate study. A needs assessment in the summer of 1977 identified four nationally important and relevant areas which PROCEED should address: industrial energy conservation, protection of workers and users from toxic substances, alternative energy sources, and waste treatment management. We developed the first topic during 1977 to 1979, the second is being developed, and the last two will be developed later.

Our first topic is Industrial Energy Conservation. Professor Elias Gyftopoulos of the Department of Nuclear Engineering is editor-in-chief of this series of modules and cases. A focused effort to find and develop problem-solving cases was made by teams of professors and graduate students in different parts of the country during the summers of 1977 and 1978. The information derived from these intensive efforts was used to determine the competencies required. These cases also are integral components of the system. We fieldtested the modules and the entire system during the last fiscal year.

Our second topic, which we are developing in a manner similar but not identical to that of Industrial Energy Conservation, is Protection of Workers and Users from Toxic Substances. To this end, we have enlisted the support of Professor Nicholas Ashford and several of his staff from the Center for Policy Alternatives.

In addition to the modules and cases, we have developed a computer-based "adaptive reference system" which helps the user to define his or her problem and to find relevant educational materials. The adaptive reference system is based on an analysis of the problem structure, and therefore teaches "know-how" as well as knowledge.

This novel approach to continuing education has attracted a great deal of interest. Late in 1979, we were invited by Congressman Rose to study the feasibility of applying the PROCEED System to the House Information Services as a means of teaching new members of Congress how the budgetary process works. We are now planning this project. We also are conducting experiments funded by Control Data Corporation to introduce PROCEED modules onto the PLATO System and deliver the entire system electronically.

We currently are facing the usual problems associated with renewal funding. NSF refused renewal since industry is funding on-line developments, and toxic substances are in the purview of a mission agency.

Project TRANSMIT

Project TRANSMIT is a research project, begun during the last fiscal year, to evaluate various modes of communication to engineers and scientists to determine which are pedagogically most effective. The modes are lecture, reprint, audio cassette, microfiche, and on-line access.

During the first six months we gathered data on all five modes. Survey forms and telephone interviews were used to determine what use purchasers made of information on reprints, cassettes, or microfiche and how they were influenced by attendance at lectures or on-line access. The American Institute of Chemical Engineering has cooperated by making their membership data base available.

Preliminary results suggest that on-line transmission is the least likely mode of successful communication and may not be considered in the final analysis. Final results will be submitted to the NSF, the project sponsor. Professor Cohen is the director and principal investigator of this project.

Thermoeconomics

This research project is concerned with the development of a new discipline in which the principles of thermodynamics, engineering economy, and optimization are combined and applied to the analysis of systems which convert or use energy.

The aim is to develop an approach similar in philosophy to the conventional approach to the thermodynamic analysis: to stimulate creative designs of systems, as well as to develop an analytic method of improving the allocation of capital and energy resources within a system.

MYRON TRIBUS

Center for Policy Alternatives

The Center for Policy Alternatives (CPA) completed its eighth year under the direction of Professor J. Herbert Hollomon. CPA differs from most policy research centers in that it is action-oriented -- developing alternative policies, identifying various means for implementing them, and evaluating the possible consequences of their implementation. CPA's objectives are to identify and study important emerging social issues in which technology and engineering play a significant role, to assess the consequences of established institutional policies and develop alternatives available to decision makers, and to provide students and professionals with research and training opportunities in policy analysis and formulation.

RESEARCH ACTIVITIES

CPA's net sponsored research volume, excluding major subcontracts, has grown from \$89,000 in fiscal year 1973 to \$1,237,000 in fiscal year 1980. This past year, net sponsored research dollars were up \$304,000 from a total of \$933,000 in fiscal year 1979. Project support during fiscal year 1980 was wide ranging and included nine US government sponsors, three foreign government sponsors, nine industry sponsors, and two foundation sponsors, as well as support from the United Nations and the World Bank.

Technology, Innovation, and Public Policy

For the past several years, the role of government policies in meeting social demands for new technology has been an important research concern of the Center. Previous CPA studies have examined factors that influence technological change and innovation in such diverse settings as the United Kingdom, the Netherlands, West Germany, France, Japan, Brazil, Venezuela, and the countries of the Sahel-Sudan region in Africa. In addition to disseminating the results of these studies among nations, the Center has accumulated knowledge and insight into the nature of the innovation process in several national contexts and the role of governments in encouraging

innovation. While one nation's policies and programs are not necessarily applicable to another, the knowledge of how these governmental mechanisms operate within different political, economic, and social environments, coupled with an understanding of the innovation process itself, can suggest ideas for new policies and programs to improve the national climate for innovation.

A significant accomplishment this past year was the completion of a 22-month study of government policies to encourage industrial innovation in Israel. This project was supported by the Office of the Chief Scientist in the Israeli Ministry of Industry, Trade, and Tourism (MITT), and was financed in part through a loan to the Israeli government from the World Bank. Israel has one of the more comprehensive set of government incentives for industrial innovation including grants, loans, and tax rebates. With the assistance of the Interdisciplinary Center for Technological Analysis and Forecasting (ICTAF) at Tel Aviv University, CPA examined in detail the organization and administration of the research and development incentives program of the MITT.

To highlight the completion of research for the US Department of Commerce in connection with President Jimmy Carter's Domestic Policy Review on Industrial Innovation, CPA initiated and sponsored an international symposium on Technology, Innovation, and Industrial Development in October. The two-day symposium was attended by over 260 decision makers, planners, and analysts from 10 nations, and the participants included university, government agency, labor, and industry leaders. Conference presentations focused on factors that affect technological innovation in the United States, and recommendations for the development of effective US technology policy and for the management of innovation in industry were debated at length. *Technological Innovation for a Dynamic Economy*, based on the papers prepared for the Domestic Policy Review and edited by Dr. Christopher T. Hill and Dr. James M. Utterback, was published by Pergamon Press, New York, just prior to the conference and provides a detailed discussion of many of the provocative ideas presented at the symposium.

A number of the recommendations for consideration by the President and the US Congress are of continuing interest and concern to the Center for Policy Alternatives including:

- 1) Modifying regulatory approaches to encourage innovation and diminish the harmful effects of industrial activity;
- 2) Developing a more comprehensive system for anticipating industrial changes and accelerating support for retraining and relocating workers; and
- 3) Initiating a major program of support in industry and the universities for the development of industrial technology.

As a result of the previous work of the CPA in the area of technological development and public policy, three new research opportunities have come to CPA during the year under review. The first involved CPA's participation on the Innovation Task Force of the Solar Energy Research Institute (SERI) Solar/Conservation project for the United States Department of Energy. The overall project objective is to develop a coordinated set of government policies designed to minimize US consumption of nonrenewable energy sources by shifting toward renewable energy sources and more efficient use of all forms of energy. CPA participants included Dr. Hill, principal investigator, Dr. W. Curtiss Priest, George R. Heaton, Jr., Richard Frenkel, Francine Mancini, and graduate student, Stuart A. Batterman.

The second research opportunity is a collaborative project with the Korean Institute for Science and Technology (KIST) for the Ministry of Science and Technology (MOST). The project is funded by the United Nations Development Program with the World Bank acting as the executing agency. The purpose of the study is to suggest policies and courses of action for technological improvement in Korean industry. Dr. Hollomon and Dr. Rao are principal investigator and project manager, respectively, and project participants include Dr. Hill; Dr. Utterback; Professor Raymond F. Baddour, Department of Chemical Engineering, Professor Koichi Masubuchi Department of Ocean Engineering; Professor Donald R. Lessard, Sloan School of Management, and several graduate students.

The third study is now under way in cooperation with personnel from the National Swedish Board for Technical Development (STU), the sponsoring agency. As an industrialized country,

Sweden, like the US, must look toward technological innovation and the effective use of new technology in industry while renewing its industrial structure. STU is particularly interested in the degree to which newer and smaller technology-based firms are vital to the Swedish economy. For comparative purposes, a survey and analysis of new small firms in the US is planned. Under the direction of Dr. Utterback, the project team includes Dr. Hollomon, Professors Edward B. Roberts and Thomas J. Allen, Jr., Sloan School of Management, and Professor Harvey M. Sapolsky, Department of Political Science.

As the year closes, CPA has been invited to participate in an 18-month study of technological development in Portuguese industry. This project, to begin in the fall of 1980 under the management of Dr. Rao as principal investigator, is sponsored by the Laboratório Nacional De Engenharia E Tecnológica Industrial (LNETI). LNETI is an umbrella organization under which several research and testing laboratories of the Ministry of Industry and Commerce have been consolidated.

Relationships Between Regulation and Innovation/Technological Change

The United States has tended historically to lead the world in the development of regulatory policy designed to control and direct technological change and thereby minimize the adverse consequences of technology. Depending upon the circumstances, environmental, health, and safety regulation can act to inhibit, stimulate, and/or redirect technological innovation. To further the understanding of the interaction of regulation and innovation, the Center for Policy Alternatives has been studying three of the most highly regulated industrial sectors in the US -- the automobile, chemical, and pharmaceutical industries.

CPA completed the first phase of a major study focusing on regulation and technological change in the foreign automobile industry. The study documents selected technological changes which have occurred in West Germany, Sweden, and Japan in response to US emissions control, fuel economy, and safety regulations. Further work will compare the US and foreign experience in various policy areas including government support for the development of automotive technology, which may suggest new initiatives for future US policy. Sponsored by the Department of Transportation, the study is complemented by a related research effort to examine environmental regulation of the automobile which was funded by the Environmental Protection Agency. The research team includes Dr. Nicholas A. Ashford, principal investigator; Mr. Heaton, project manager; Dr. Priest and Dr. Hill; and colleagues from the Science Policy Research Unit at Sussex University, United Kingdom, and the Institute for Policy Sciences at Saitama University, Japan.

The Environmental Protection Agency asked CPA to develop policy options designed to minimize the potential adverse effects of the new Toxic Substances Control Act (TSCA) on innovation in the chemical industry. Based on a comprehensive review of the literature on innovation in the chemical industry and on a general understanding of the influence of regulation on innovation, CPA researchers developed 32 policy options to offset the unnecessarily restrictive impacts of TSCA on chemical innovation. An evaluative technique was designed to rank the policy options relative to each other, and seven policies were judged by the project team to be superior to the others overall. CPA project members recommended that EPA consider a comprehensive program of policies designed to reduce directly the costs of new chemical development, to provide more information, to improve compliance technology, and to modify administrative procedures for managing Premanufacturing Notifications. While no single policy can be expected to offset all of the unnecessarily restrictive impacts of TSCA on innovation, the CPA analysis suggests that a program of combined policy elements can be effective and need not be very large, expensive, or disruptive. Project team members included Dr. Ashford, Dr. Hill, Dr. Priest, Mr. Heaton, Mr. Frenkel, and graduate students Richard A. Andrews and Clifford S. Mitchell.

As the development of pharmaceuticals in the US has met with increasingly stringent Federal controls intended to protect the consumer from deceptively labelled, dangerous, and/or ineffective products, there has been a growing sense that this consumer protection has changed the nature of pharmaceutical innovation. CPA discovered that while a substantial amount of research has sought to assess the impact of regulation on pharmaceutical innovation as a whole by examining changes in the output of new drugs in the US or through international comparisons, little work has focused on comparisons of 1) regulatory policies, 2) innovation processes, and

3) innovative output and drug benefits for different therapeutic classes of drugs. In preparation for undertaking such research, CPA completed Phase 1 of an NSF-sponsored project to identify, within therapeutic classes, characteristics of drugs which may be expected to differ importantly in the above three areas. This was accomplished through the definition of specific aspects of regulatory and non-regulatory influences, drug innovation processes, and types of drug benefits which lend themselves to reliable assessment in order to test hypotheses about changes in the pattern of drug innovation. Phase II of the work is expected to begin in fall 1980 under the direction of Dr. Ashford, principal investigator, and Dr. Dale Hattis, project manager. Project participants will include Mr. Andrews, Dr. Priest, and Dr. J. Worth Estes of the Boston University Medical School.

Public Welfare Consequences of Environmental, Health, and Safety Regulation

Recently, regulatory programs have been strongly criticized on the grounds that they impose substantial costs on business, the consumer, and society. These views have been reinforced by a national focus on the costs rather than the benefits of environmental, health, and safety regulation. It is clear that while benefits do exist for these regulations, they are much more difficult to measure quantitatively than the costs of regulation. Therefore, it is particularly appropriate that the extent and nature of the gaps and limitations in the state-of-the-art of benefit estimation be understood. CPA undertook a major new study of the benefits of environmental, health, and safety regulation this past year to contribute to an improved understanding of these issues.

Sponsored by the US Senate Committee on Governmental Affairs, the initial research effort was a three-month project to compile and characterize over 350 existing private and public sector studies on the benefits of regulations in the areas of air and water pollution, automobile safety, consumer product safety, pure food and drug, and workplace safety and health. The study is the first major effort of its kind to assemble all the known information on the achievements of Federal environmental, health, and safety programs. The two-volume report, written by Dr. Ashford, Dr. Hill, Dr. Hattis, Dr. Priest, and Dr. William M. Mendez, Jr., included a framework for analyzing the benefits of regulation, summaries of the principal findings of selected major studies of regulatory benefits, and a complete bibliography of the literature with abstracts of over 165 documents. Under the direction of co-principal investigators, Drs. Ashford and Hill, this research team is now engaged in an 18-month study funded by the Environmental Protection Agency (EPA) to extend the analysis begun in the study commissioned by the Senate Committee on Governmental Affairs on the benefits of environmental, health, and safety regulation.

In October, CPA completed the development of a methodology to assess the economic and health impacts of occupational safety and health standards. The project was sponsored by the Occupational Safety and Health Administration (OSHA) of the US Department of Labor (DOL). The purpose of the work was to aid OSHA in structuring its information-seeking and analytical efforts for health standards in ways which would be useful both in arriving at appropriate health standards decisions and in satisfying formal requirements for assessing the health and economic impacts of its proposed actions.

A related research project was completed for the DOL Office of the Assistant Secretary for Policy, Evaluation, and Research. Dr. Ashford, principal investigator, Dr. Priest, project manager, and Mr. Frenkel, examined trends in worker perception of occupational safety and health hazards using data obtained from the Quality of Employment surveys taken in 1969, 1972, and 1977.

A 20-month EPA-sponsored research project on hypothetical relationships between noise, stress, and cardiovascular disease was completed by Drs. Ashford and Hattis in November. The study examined cardiovascular disease processes, delineated possible ways in which high noise exposures may contribute to these processes, and assessed approaches for future research.

The public health risk of exposure to benzene was the focus of a study completed this past year by Drs. Ashford, Hattis, and Mendez for the EPA Office of Air Quality Planning and Standards. The project provided a brief analysis and critique of the risk assessment for general population exposure to benzene which was performed by the Carcinogenicity Assessment Group (CAG) of the EPA.

Design of Future Environmental, Health, and Safety Regulation

In December 1977, the DOL Occupational Safety and Health Administration asked members of the CPA staff to explore broad new issues in occupational safety and health and to develop new strategies and initiatives available to OSHA for reducing occupational injury and disease. The 22-month study was completed in September and included:

- 1) an examination of the legal and technical issues related to removal of workers from hazardous conditions
- 2) an examination of the effects on direct labor costs of providing earnings protection for removal of workers from hazardous conditions in the proposed lead standard
- 3) a study of supplementary approaches, such as tax incentives and medical removal protection, in addition to the standards approach to safety, and
- 4) an investigation and analysis of alternative mechanisms for improving the effectiveness of standards and non-standards approaches to the prevention of occupational injury and illness.

One new issue is the relationship between regulation and the private legal system. The project team examined all tort cases dealing with occupational disease as a basis for analyzing the suitability of the common law tort system as a mechanism for effecting improvements in work place conditions. In addition, the issue of feasibility in OSHA standard-setting and enforcement was addressed by a review of the case law resulting from petitions for judicial review of the lead and benzene standards. The development of a cost/benefit methodology for determining feasibility in judicial contexts was an important outcome of the CPA research. Project participants included Dr. Ashford, principal investigator, Mr. Heaton, Dr. Priest, Dr. Hattis, Dr. Mendez, Mr. Frenkel, and Sally Owen.

A current issue of concern to the National Institute for Occupational Safety and Health (NIOSH) is the establishment of Federal research priorities in order to better regulate exposure to radiation. A CPA research project, sponsored by NIOSH, reviewed the extent to which social needs for research on the biological effects of ionizing radiation are being met by the existing structures for funding such research, and the procedures by which such research is used to inform social policy decisions. Preliminary data gathered by Drs. Ashford, Hattis, and Mendez, revealed that there are important gaps and inconsistencies in regulatory structure. For example, the Federal standard designed to limit exposure of uranium miners to radiation seems to allow a much higher risk than standards designed to protect other workers. A number of issues were identified which warrant further investigation, and CPA is likely to receive NIOSH funding for a six-month follow-up study.

Manufacturing Technology and Industrial Productivity

Among the factors that are creating new interest in the use of manufacturing technology are the increasing emphasis on computers and micro-electronics, growing social concerns for the welfare of the worker and the consumer/user, increasing international competition for world markets, and changing availabilities and costs of resources used in the manufacturing process such as energy, materials, and human skills. New policies, new approaches, and fresh insights are needed which require careful analyses of this rapidly shifting set of circumstances. The Center for Policy Alternatives is engaged in five research projects in this area which address issues such as the impacts of automation on industrial firms, opportunities for remanufacturing, the potential for computer-based materials processing, and the process of technology transfer.

This past year saw the beginning of a major new initiative for the Center for Policy Alternatives. The Advanced Technology and Industrial Productivity (ATIP) Program is to be a long-term experiment in industrial and academic cooperation to achieve an understanding of the nature and consequences of changes brought about by new forms of manufacturing technology, particularly those based on computers. The Caterpillar Tractor Co. is the initial sponsor, and the first research project is a case study of the introduction of new machinery in a tractor components manufacturing building. The study examines the selection of the new technology, the process of converting from conventional to new machinery, and the effects of the change on labor, management,

the organization, the product, the economics of the firm, and the community. Project participants to date include Robert T. Lund, principal investigator, Dr. Hollomon, Dr. Utterback, and graduate student Vera Ketelboeter.

Continued funding was received from the Department of Energy (DOE) for Phase II of the research program directed by Mr. Lund to evaluate the potential for remanufacturing durable products in the United States as an approach to energy and resource conservation and the reduction of solid waste materials. Project participants include Lynn Bollinger, Professor Joel P. Clark, of the Department of Materials Science and Engineering, Dr. Floyd Tuler, and graduate students Chris Barnett, Avinash Deolalikar, Richard Kutta, and Clint Stanovsky.

The Computer-Aided Materials Processing (CAMP) project explores the opportunities for computer control of materials processing techniques in casting, extrusion, forging, and powder metallurgy. Managed by Mr. Lund, the CAMP effort is part of a larger research program at MIT funded by the National Aeronautics and Space Administration (NASA) to develop a materials processing research base under the direction of Professor Merton C. Flemings, Jr., of the Department of Materials Science and Engineering.

Technology transfer is a topic currently attracting much attention, but it has had little documentation to date. Under a National Science Foundation (NSF) program to study innovation processes and their management, Mr. Lund and Richard Goldhor are investigating an instance of successful technology transfer from an academic research group to a small private company. The study will document and analyze the transfer of a software system for translating English text to speech, developed by the Natural Language Processing Group at MIT, to Telesensory Systems, Inc., in California, which provided the necessary optical character recognition technology to develop a reading machine for the blind. An analysis of this case study is expected to provide insights into some of the problems involved in effecting technology transfers from the academic world to the business world.

Another set of technology transfer issues is being addressed by a seven-month research study of the transfer of defense technology to the civilian sector, with implications for the development of conversion policies in rapidly developing countries. Funded by the United Nations Centre for Disarmament, the project examines the development of three substantial aircraft industries in Brazil, Israel, and India and if and how these industries have exploited non-military markets for aircraft. The report will be completed during the summer of 1980 by co-principal investigators Dr. Rao and Professor Jack Ruina, Electrical Engineering and Computer Science, with the assistance of Dr. Anselm Yaron, visiting scholar and research associate; Bernd Deckenbach, visiting intern from the University of Konstanz in West Germany, and graduate students Robert Desourdis and Kumar Nochur.

Office Automation and Information and Communications Systems

The social, economic, and public policy implications of new developments in the technology of information handling, communications systems, and office automation are of continuing interest to the Center for Policy Alternatives. Together with Professor James Driscoll, Sloan School of Management, Dr. Marvin A. Sirbu, Jr., directed a seven-month project which reviewed and compared 36 existing in-house office automation studies, reports, and planning documents from six sponsor firms and several additional companies. Professor Robert Alloway, Sloan School of Management, and Professor Michael Hammer, Department of Electrical Engineering and Computer Science, also contributed to the project.

The "Office of the Future" was the focus of a two-day ILP symposium in June, chaired by Dr. Sirbu with the participation of faculty from the Sloan School of Management, the Department of Electrical Engineering and Computer Science, and the Department of Architecture. The conference attracted 275 participants interested in the results of recent research at MIT on office automation. The sessions focused on methodologies for studying an office system, guidelines for planning for office automation, organizational issues such as centralization versus decentralization of equipment, and the public policy implications of extending office automation technology to inter-firm communications.

As part of MIT's Research Program on Communications Policy, Professor Ithiel de S. Pool of the Department of Political Science and Professor Ruina directed a 15-month curriculum development project which was administered through CPA. Sponsored by ITT Corporation, the project involved developing the content of a four-day customer education program on new technologies in telecommunications and their implications for service and investment planning. Project participants included Dr. Sirbu, project manager; John Ward of the Laboratory for Information and Decision Systems; Professor David Staelin of the Department of Electrical Engineering and Computer Science; Herbert Dordick, visiting scholar at the Center for International Studies; and Richard Solomon, temporary research associate at CPA.

This past spring, Dr. Sirbu served as co-chairman of the Eighth Annual Telecommunications Policy Research Conference. The conference is the only national professional meeting in the communications policy field. Each year, the multi-sponsored conference brings together academic researchers and government policy makers to exchange findings and views on new telecommunications technologies and services and the policy implications of these developments.

EDUCATIONAL ACTIVITIES

Teaching and advising students is an integral part of CPA activities. Several CPA staff members teach courses each year in the School of Engineering and in the Sloan School of Management. In addition to seeking the active participation of undergraduate and graduate students in CPA research projects, members of the staff advise Bachelors, Masters, and Ph.D. candidates from a variety of MIT departments and interdisciplinary programs.

A number of new educational initiatives were taken during fiscal year 1980 that are worthy of mention. CPA staff members contributed to the development of a new Masters program, designed and taught three new graduate courses, participated in MIT's Independent Activities Period, and began the preparation of a teaching case under a grant from the Duke/Rand Public Policy Curricular Materials Development Program.

Dr. Hollomon and Dr. Edward Roberts, Sloan School of Management, led the development of a new Master of Science program on the Management of Technology, to be offered jointly by the School of Engineering and the Sloan School of Management. Designed for individuals who have at least an undergraduate degree in science or engineering and five to ten years of industrial or government experience, the proposed new program will prepare these individuals for more senior roles in managing technology-based programs and organizations. The new program was approved by the Committee on Graduate School Policy this past year, and it is anticipated that the program's first students will begin in the summer of 1982.

Three new graduate courses were developed and taught by members of the CPA staff. The Regulatory Framework and Environmental Decision Making was offered by Dr. Ashford, Dr. Hattis, and Ms. Owen as part of a special summer graduate course for professionals on the Principles of Toxicology. Government and the Chemical Process Industries was initiated and taught by Dr. Hill through the Department of Chemical Engineering. Common Carrier Telecommunications Technology and Policy was sponsored jointly by the Departments of Political Science and Electrical Engineering and Computer Science, and was taught by Dr. Sirbu and Dr. Pool.

As part of MIT's tenth Independent Activities Period, Dr. Sirbu taught Introduction to Telecommunications. The activity offered an overview of current and evolving communications technology and attracted 12 participants.

The teaching case which Dr. Sirbu is preparing is a chronological review of the events which led the US Postal Service to propose a new Electronic Computer-Originated Mail Service. Unlike the rest of the world, the Post Office and telecommunications operations in the United States have been separate from their beginnings. Thus, the emergence of electronic mail technology as a significant threat to the Postal Service poses complex questions as to the appropriate role for the Postal Service in the electronic age. The case examines the interplay between the Postal Service and the telecommunicatins industry, their regulators, and congressional supporters. At MIT, the case will be used in technology and policy courses as well as in courses which study the policy-making process.

FACULTY, STAFF, AND STUDENTS

The CPA staff includes 3 faculty, 10 permanent research staff, 11 temporary and visiting research staff, 3 exempt and administrative staff, and 10 support staff. In addition 49 MIT students and 8 students from area universities worked with the CPA staff over the past year as research or teaching assistants. Of the MIT students, there were 41 graduate students and 8 undergraduates, including 4 UROP students.

Dr. Marvin A. Sirbu, Jr., was promoted to Principal Research Associate and was appointed a lecturer in the Department of Mechanical Engineering. Dr. James M. Utterback was appointed Associate Professor of Engineering. In December, Dr. Hollomon was hospitalized as the result of a stroke, and Dr. Utterback served as acting director of the Center for Policy Alternatives through May, when Dr. Hollomon resumed his responsibilities as director.

The resignations of Sally Owen, research associate; Judith Katz, research associate; and Patricia Alexander, assistant to the director; were accepted with regret. Ms. Owen has joined the law firm of Winer and Abrams in Boston, Massachusetts. Ms. Katz is practicing labor law for the National Labor Relations Board in Washington, DC. Ms. Alexander is pursuing graduate studies in the health care field at Boston University.

The Center for Policy Alternatives welcomed a number of visiting researchers from US and foreign institutions during the past year. Professor Roger Chisholm, on leave from the Department of Economics at Memphis State University in Tennessee, and Dr. Benjamin Ross of The Analytical Sciences Corporation (TASC) in Reading, Massachusetts, worked as visiting research fellows with Dr. Ashford and others on the DOL project to develop a methodology to assess health and economic impacts of occupational safety and health standards. Professor Floyd Tuler, visiting research fellow, participated in the Israel Innovation study and the DOE Remanufacturing project while on leave from the Materials Science Division of Hebrew University in Jerusalem, Israel. Dr. Anselm Yaron, head of the Weapons Systems Development Program of the Israeli Ministry of Defense, collaborated with Drs. Rao and Ruina on the UN-sponsored Disarmament and Development study. For the fifth year, CPA was pleased to host two graduate research interns from the University of Konstanz in West Germany. Messrs. Bernd Deckenbach and Thomas Schmitt held visiting research specialist appointments and worked with Dr. Rao. Professor Wolfgang Bruder, visiting research fellow from the University of Konstanz, worked with Drs. Utterback and Rao on the study of innovation in Swedish and Portuguese industry. Byung Gon Yoo, a researcher with the Industrial Economics Division of the Korean Institute of Science and Technology, contributed to the Korean project in his capacity as visiting research specialist.

J. HERBERT HOLLOWOMON

Center for Transportation Studies

The Center for Transportation Studies (CTS) was established in 1973 to coordinate transportation activities at MIT. CTS provides the intermodal and interdisciplinary linkages for transportation research and educational activities at MIT involving over 50 faculty members from the following departments: Aeronautics and Astronautics, Architecture, Civil Engineering, Humanities, Economics, Electrical Engineering, Mechanical Engineering, Ocean Engineering, Political Science, the Sloan School of Management, and Urban Studies and Planning.

The CTS Executive Committee meets monthly to oversee the operation of the Center. Members of the Executive Committee include Professor Herbert Richardson, Mechanical Engineering; Professor Alan Altshuler, Political Science; Professor Marvin Manheim, Civil Engineering; and Professor Robert Simpson, Aeronautics and Astronautics.

This annual report focuses on three major initiatives of CTS: the Transportation Masters Program, an international study of the future of the automobile, and formation of the CTS Advisory Committee to provide external review of activities.

Transportation Master's Program

A new interdepartmental master's program in transportation was offered for the first time this past year. The program provides a broad multimodal and interdisciplinary perspective on transportation, and is designed to complement rather than replace existing departmental programs in transportation. Students with diverse interests in transportation would pursue the master's program, whereas those students with more narrowly focused interests related to a specific transportation mode would pursue an existing departmental program.

A basic component of the new master's program is a set of core courses to provide the perspective, background, and disciplinary foundations of transportation. Extensive time went into the planning and development of the following six new core subjects:

CTS 100 Basic Concepts in the Analysis of Transportation Systems
CTS 110 Transportation Economics
CTS 120 Transportation Institutional Analyses and Policy
CTS 130 Issues in Transportation Management
CTS 140 Transportation Performance and Technology
CTS 150 Transportation Demand and Activity Analysis

An eight-member faculty committee under the leadership of Professor Nigel Wilson is responsible for administering the new master's program. Committee members represent four engineering departments, as well as Economics and Urban Studies and Planning. The committee meets monthly and is the major forum for all important decisions about the program.

This year the first pilot group of students was admitted to the program, all six core subjects were taught for the first time, curriculum development efforts began with follow-on subjects to the core, and the first full-scale publicity and admissions cycle was completed.

Last September, the first three students admitted to the program matriculated and these were joined by 10 others during the course of the year. (Five new students were admitted in January and five students transferred into the program from existing departmental programs.) In June of this year, the first three students to complete the degree requirement graduated.

All six core subjects were taught successfully after a significant effort was devoted last summer to their development. Student enrollment varied from 15 to 40, indicating that in each case the subject served a significantly wider clientele than just students in the new master's program. Recently, a half-day meeting was held and attended by the faculty involved in teaching the core subjects to review in detail initial experiences with the core courses. For each course, improvements were identified which will be introduced in the subjects during the coming academic year.

The curriculum development effort this past year has shifted its focus to the follow-on subjects beyond the core. Existing advanced subjects are being modified where necessary so that they build on the appropriate core subject, and new subjects are being developed where gaps currently exist. Activity during the past year focused on development of the following new subjects: Advanced Performance Models, Vehicle Dynamics, Economics of Marine Systems, and Transportation Policy Analysis.

These subjects provide additional depth in the areas of transportation systems analysis, technology, economics, and policy. In each, the new offerings are being carefully coordinated with related advanced subjects as well as with the core program.

A top priority for the coming academic year, in terms of curriculum development, is further enhancement of the transportation management area by developing one or more coordinated subjects beyond the core subject. This was not initiated in the past year because of the effort required to develop a new management core subject and the absence of both Professors Henry Marcus and Gerald Sussman who were on sabbatical leaves.

This year represented the first complete admissions cycle, so a significant effort was made to publicize the program. Posters announcing the program with mail-back cards were sent to most US universities, and announcements were also issued to professional journals. As a result, well over 500 inquiries about the program have been received since last September.

A total of 75 admission applications were received, and 40 offers of admission were made, with an expected 25 students matriculating in September. This number is already, even in the program's first full year, close to the planned level of 30-50 students in the program each year.

To help evaluate the effectiveness of the publicity and of the program itself, some 200 questionnaires were sent to a sampling of those who had inquired about the program but not yet applied. About 50 percent of those surveyed returned the questionnaire, with some of the major findings being:

- more than one-quarter of those responding plan to apply to the master's program at MIT in the future
- more than one-third did not plan to pursue a graduate degree.

In addition, several suggestions were made which will be used to improve the admissions publicity effort next year. All told, the master's program got off to a good start, and it appears that next year there will be a large enough number of students enrolled to allow an in-depth review of the new program, which is planned for next summer.

International Auto Study

The Center has initiated a major international project to explore the future of the automobile. Initial funding for this four-year, \$5 million dollar project has been secured from the German Marshall Fund of the United States. The Board of the Marshall Fund also has indicated a willingness to make a significant additional grant if MIT succeeds in obtaining matching funds from other sources.

The project consists of an interrelated set of research investigations and international workshops which explore current auto strategies and future policy options for guiding automobile technology in socially desirable directions. The research is conducted jointly by the MIT Center for Transportation Studies and the MIT Center for International Studies, in collaboration with a network of foreign research teams. To date, teams have been established in France, Germany, England, Sweden, and Japan. Each team is responsible for examining the role of the automobile in its own specific national context so that consistent international comparative analysis can be performed. The workshops bring together government officials, management and labor representatives from the auto industry, spokesmen for environmental and consumer interests, and other key opinion leaders and decision makers from a number of different countries.

The underlying premise of the project is that the automobile stands today at the nexus of a complex set of forces which influence profoundly the economies, environment, and social conditions of all Western countries. Automobile-related decisions of government and private industry in Europe, North America, and Japan vitally affect those countries' level of employment, balance of trade, market for natural resources, energy demand, and environmental quality, and the shape of their cities and lifestyles. It is not surprising, therefore, that ensuring a socially desirable evolution of the motorcar has become a major concern of all industrially advanced countries.

The aim of the project is to create a neutral forum where future policy options relative to the automobile can be explored and debated from a long-range global perspective. The intent is to inform public discussion and improve the quality of analysis that must underlie enlightened public decisions concerning the future of the automobile.

The project includes examination of the roots of current policies and business-government relationships, comparison of the priorities and implementation strategies, and appraisals of the significant technological policy options likely to be available in coming years.

It focuses particularly on the evolution of national priorities between promotional objectives (for example: to expand employment and exports), and regulatory objectives (for example: to conserve energy, reduce air pollution, and enhance safety), and on the national strategies for accelerating the pace of technological innovation in the auto industry. In addition, the project considers such key policy issues as the impact of the "world car" on international trade motor vehicles; various strategies to control and modify the use of automobiles as an element of national energy and environmental policies; and the global implications of rising automobile demand in the countries of the developing world.

To help launch the new project, the Center for Transportation Studies presented a major seminar series on the future of the automobile. Speakers included Neil Goldschmidt, Secretary of the US Department of Transportation; Fred Secrest, Executive Vice President of the Ford Motor Company; Irving Bluestone, Vice President of the United Auto Workers, and William Abernathy, Professor at the Harvard Business School.

Co-directors of the project are Professor Daniel Roos, Director of the Center for Transportation Studies, and Professor Altshuler, Head of the Political Science Department.

Other members of the project team include Professors William Abernathy (Harvard Business School), Ann Friedlaender (MIT Departments of Economics and Civil Engineering), and James Utterback (MIT Center for Policy Alternatives).

CTS Advisory Committee

The CTS Advisory Committee was formed this year to provide external review of ongoing CTS activities and to advise on new CTS initiatives. Although each department at MIT has an outside visiting committee, it is unusual for such a group to be formed for a center or laboratory. Denman McNear, Class of 1948, and President of the Southern Pacific Railway, will chair the new advisory committee. Other members of the committee include:

James R. Barker
Chairman of the Board, Chief Executive
Officer
Moore McCormack Resources, Inc.

Morton Ehrlich
Senior Vice President, Planning
Eastern Airlines, Inc.

William J. Harris, Jr.
Vice President
Research and Test Department
Association of American Railroads

Semon E. Knudsen
Chairman of the Board
White Motor Corporation

C. Kenneth Orski
Vice President
German Marshall Fund

William K. Smith
Vice President, Director of
Transportation
General Mills, Inc.

Richard L. Terrell
Retired Vice Chairman
General Motors Corporation

John J. Terry
Group Vice President, Land Transportation
IU International Management Corporation

Alan M. Voorhees
Founder A.M. Voorhees & Associates

Melvin M. Webber
Director
Institute of Urban and Regional Development
University of California at Berkeley

Christopher R. Willoughby
Director, Transportation, Water and Telecommunications
The World Bank

Daryl D. Wyckoff
Professor, Graduate School of Business Administration
Harvard University

Other Activities

CTS supports a diverse research program exceeding \$2 million per year. Major projects include transportation energy contingency planning in the United States, the impact of deregulation on transportation carriers, state transportation programs to minimize harmful environmental impacts, railroad network operations and management, and urban transportation parking policies. An increasing research emphasis is being directed toward transportation in developing countries. Research projects exist in Egypt and Nigeria, and a new joint project with Brazil was begun.

To provide opportunities for practicing transportation professionals to acquire new perspectives and techniques, CTS offers a coordinated series of transportation summer programs. Some of these programs are focused on a particular mode or topic area, while others are designed to provide general coverage of basic concepts and techniques. Participants in any individual program are able to attend selected sessions of other programs. Seven coordinated programs were presented last year attracting more than 150 students.

CTS sponsors a weekly seminar series which this past year featured 25 outside speakers. These seminars attract an audience of more than 60 people per week.

A book series on transportation coordinated by CTS through the MIT Press publishes approximately five books per year. In addition, MIT research reports and a quarterly newsletter are distributed by the Center.

DANIEL ROOS

Innovation Center

The MIT Innovation Center was formed in 1973 with National Science Foundation funding as an experiment in innovation education. During the past academic year, the Innovation Center has continued to develop its program in order to provide MIT students with supplementary education focusing on innovation and entrepreneurship.

The Center offers two classroom subjects in its educational program. A graduate/undergraduate subject on invention and a graduate/undergraduate subject on entrepreneurship. About 90 students participated in these two subjects during the past year, the major part of this group being graduate students from the engineering departments.

The principal area of research includes the development of an invention evaluation methodology, investigation of ways to develop human resources to improve the innovation base for energy-related technology, and work on commercialization of energy-related inventions. This effort has been sponsored by the National Bureau of Standards and the Department of Energy. Eight research assistants have participated in this work.

The product development activity of the Innovation Center has included four projects during this past year. Three undergraduate students, one graduate student, two part-time staff members, and three visiting scholars have been involved in this work under the guidance of four faculty members. The total funding level for this past year was approximately \$350,000. Nine faculty members have contributed to the various activities of the Center.

Major program development has begun in order to increase cooperation between the Innovation Center and industry. Such cooperation will enhance all three facets of the Center's program: education, research, and product development. It is intended that this linkage will expand both faculty and student participation in the Innovation Center. A second area of interest is the development of cooperation between the Center and developing countries. During the past year, discussions with individuals from India have brought us close to establishing a relationship with various Indian institutions.

A book entitled, *Technological Innovation in Education and Industry* by Professors Yao Tzu Li, David G. Jansson, and Ernest G. Cravalho was published by Van Nostrand Reinhold in May 1980.

DAVID G. JANSSON

Materials Processing Center

The Materials Processing Center was formed within the School of Engineering in August 1979, and was officially inaugurated in February 1980. Center activities encompass all engineering materials including metals, ceramics, polymers, electronic materials, composites, superconductors, and thin films. The formation of the Center reflects the growing interest and involvement of the materials community at MIT in technological problems relating to improved ways of producing and shaping materials so that they can perform more effectively for society's use -- and with acceptable economic and social costs.

An important underlying theme of the Center is that performance of materials can be controlled through control of internal structure, from the macroscopic to the atomic level. Another important theme is that economic and low-energy production of materials in a competitive world depends on rapid assimilation of many technologies into materials processing, and on modification and adaptation of materials processes to better utilize these technologies. The materials processing industries in the United States, long the world leaders, now have segments which are lagging behind those of other countries. Innovative materials processing developments, incorporating advanced technology, are essential if the country is to regain leadership in this area.

The Center provides a mechanism for the staff and faculty of the School of Engineering, as well as others, to contribute effectively to broad materials processing problems and opportunities. It interacts with industry and government in seeking to develop, extend, and apply the scientific and technological base of materials processing, and to broaden its educational base.

The center is currently undertaking a broad range of research activities, and is developing new curricula, seminars, and continuing education programs. It encourages and sponsors specialized research and academic appointments, including the extended residence at MIT of industry and government personnel as visiting faculty, adjunct faculty, and postdoctoral researchers. Faculty and staff participate in the Center from a number of departments at MIT, principally the Departments of Materials Science and Engineering, Mechanical Engineering, Electrical Engineering and Computer Science, and Chemical Engineering.

The current annual operating budget for the Center is \$2.7 million, of which approximately \$600,000 comprises the central "nucleus" of a broad-based grant from the National Aeronautics and Space Administration. Industrial interaction is a keystone of the Center and a number of programs within the Center involve such interaction. In addition, approximately \$700,000 of the Center's funding is provided by industry.

RESEARCH

Major thrust areas of the broad-based Center grant are 1) convection in solidification processing, 2) nucleation and rapid rate solidification, and 3) advanced computer-aided and adaptive materials processing. Professors Robert A. Brown, August F. Witt, Donald R. Sadoway, Warren M. Rohsenow, David K. Roylance, and H. Kent Bowen are working on various aspects of convection in solidification processing. Work is proceeding on metals, semiconductors, polymers, and ceramics. Professor Sadoway has initiated, as part of the Center, a new Electroprocessing Laboratory. This is an area of research that has been neglected at MIT but is of growing

importance with the need for development of energy-efficient and environmentally acceptable materials and processes. A second example is the work of Professor Witt who is designing and building a new type of vertical crystal growth system, with an interactive program on heat transfer analysis with Professor Rohsenow.

Professors Nicholas J. Grant, Frederick J. McGarry, Julian Szekely, and Merton C. Flemings are working in the area of nucleation and rapid rate solidification. This is an aspect of materials technology that shows great promise for development of new materials with unique properties, including high temperature materials, ultra-high strength materials, and "glassy" metals.

A series of workshops has been held by the Center during this past year to examine computer and robotic applications in materials processing, and to focus on how processes themselves can be altered by these new technologies. The aim of these workshops, led by Professor Robert T. Lund, is to provide the focus for future work in "adaptive materials processing."

The Center has been active in supporting and broadening the materials systems activities of Professor Joel P. Clark. Professor Clark's research combines elements of microeconomics, financial analysis, operations research, and statistical estimation with engineering analysis of the production and utilization of materials. One example of his research activities is a project on "Computer Modeling of the World Stainless Steel Industry." In this work, an engineering-based supply model of the production of stainless steel product shapes is combined with an econometric model of stainless steel demand to simulate supply, demand, and price interactions in the international stainless steel market.

The Ceramics Processing Research Laboratory, under the leadership of Professor Bowen, is an important and integral part of the Center. This Laboratory has established the specialized facilities and equipment required for processing particulate ceramic materials, and will shortly have facilities for melt processing research. The facilities in the Ceramics Processing Research Laboratory permit powder materials to be made, modified, characterized, and fabricated into finished pieces. Special glove box and controlled atmosphere pressing equipment have been established for processing high purity non-oxide powders synthesized by a novel laser-heated gas phase process.

New research programs, which have been initiated through the Ceramics Processing Research Laboratory within the last year, include basic studies of Attritor Milling of silicon carbide powders with tungsten carbide grinding media, powder formation and packing of permanent magnet materials, basic research on the theory of colloid interactions of ceramic powders, and laser chemical vapor deposition of silicon films to determine the feasibility of depositing thin films by a laser-heated gas phase process. A consortium of five companies has been formed to conduct research on the processing of BaTiO₃ chip capacitors. The National Science Foundation/Foster Laser Processing Facility has been established to conduct research in crystal growth, materials properties, rapidly quenched liquids, and powder synthesis. Three new fellowships and a grant also have been received to support graduate study in ceramic processing. A Young Faculty Support Program also has been established to support basic powder processing research.

In June, the Laboratory staff initiated a Ceramics Processing course, designed for process engineers, which was attended by 35 people representing domestic and foreign government, industry, and universities. The course will be offered again in following years.

To improve the facilities capability of the Materials Processing Center, Center funds have been used to aid in purchase of a Laser Processing Facility, to be homed in the Ceramics Processing Laboratory. This facility will give to MIT research the capabilities which are unique among academic institutions.

MERTON C. FLEMINGS

Laboratory for Manufacturing and Productivity

The Laboratory for Manufacturing and Productivity is a striking example of the potential of interdisciplinary cooperative research with industry. The Laboratory, founded in 1977 and directed by Professor Nam P. Suh, is now responsible directly to the Dean of the School of Engineering. In the past year, over 60 graduate students and 27 faculty members from six academic departments were associated with the Laboratory.

The Laboratory is unusual in the scale of its growing interaction with industry. Approximately 60 percent of its annual research budget of over \$2 million is funded by American industrial firms, both individually and through four consortia of firms. The number of innovative processes developed and the quantity and quality of patents and published papers testify to the potential of rigorous academic work sponsored by industry. Moreover, this cooperative effort enriches and broadens the educational experience of our students.

Several new programs were started this past year. Among them is a new thrust dealing with questions relating to the effects of automation and machine design on the work force and on the firm. These "human issues" of productivity, motivation, labor relations, and design processes are crucial to the continued growth of American productivity.

Also during this year, funds donated by Ralph Cross, Sr. were used to establish a lectureship in his name which will permit the Laboratory to bring leading figures in manufacturing science to MIT each year for several days of intensive workshops and presentations. In addition, Dr. Michael Packer was appointed Assistant Director of the Laboratory.

MICHAEL B. PACKER

School of Humanities and Social Science

Two problems continued to beset the School during the past year: the need for more research support in the social sciences and the need to find a better way to manage the increasingly vigorous programs in the Department of Humanities.

MIT developed strong graduate programs in the social sciences after World War II at a time when foundation and Federal government support were generous. The development of a better understanding of international and social problems was, indeed, perceived as an important national priority. In recent years, however, an increasingly self-centered Washington has become preoccupied with shorter-term issues and Federal support has diminished sharply. Economists are in greater demand than ever, and are enjoying a boom in prestige, but even economics graduate programs have suffered a marked diminution of support. As for the other social sciences, they find that they can no longer rely on the justifications that were deemed sufficient a generation ago, and must begin to develop a new rationale for their very existence. Meanwhile inflation cuts away at existing resources so that even once prosperous graduate programs now feel their very existence is in question.

There is no question that MIT can attract many of the very best graduate students in the social sciences in every field where it offers degree programs. The expectations of these programs remain high and usually they can attract a higher proportion of the graduate students they want than comparable programs elsewhere. Their competitive edge depends, however, on possessing adequate funds for supporting graduate students once they arrive. There have been difficulties in this respect in recent years, but in the past year a deliberate attempt was made to increase the competitive power of our departments. The Institute set aside more money for graduate student support and also changed the requirements for students writing theses while not in residence so that they were no longer required to pay full tuition or drop out altogether. Inflation, however, means that this process will have to be repeated year after year if we are to remain competitive. Moreover, there will be more years in which there are not enough research grants to support graduate students as research assistants. Rather than let them starve we must be prepared to provide them with short-term financial support.

The big change that has taken place in the public mood about the social sciences has fortunately been accompanied by a growing recognition that the chief employers of social scientists in the next 10 years will be government agencies, consulting firms, and corporations, rather than colleges and universities. There is, therefore, a natural tendency to look to MIT with its close connections with the non-academic world as a leader in the training of social science graduate students for non-academic employment. Thus far we have only made a few steps in that direction, but it is significant that the MIT Political Science Department is regarded as the national leader in that respect. Outside the social sciences, steps have also already been taken by the Philosophy program, which has a long-term interest in the industrial employment of philosophers, to explore non-academic employment possibilities. We clearly need to explore this whole matter further, for much of our attraction to graduate students will depend on our continuing reputation for being able to place our new Ph.D. graduates successfully.

My reports in recent years have touched so frequently on the problems of the Department of Humanities as the only department in the Institute without graduate programs, that it is pleasant to be able to report that while Federal support for the social sciences has been diminishing that for the humanities has been increasing. As a result, it becomes possible to think of research opportunities in the humanities in a more optimistic way. There is still the difficult problem of reconciling the individualistic expectations of humanists to the growing emphasis on group research and other group endeavors in the humanities. In recent years, however, historians in particular have begun to find group projects not merely useful, but exciting. A number of such group projects are now envisaged for MIT, and it begins to seem possible to plan a center where they might be housed, either in conjunction with the Program in Science, Technology, and Society or alone.

The decision during the year to experiment with further "sectional autonomy" in the Department of Humanities led us to search for a new head of that department who would also, as associate dean for humanities programs, be in a position to undertake a general oversight over future developments in the humanities. The choice fell on Professor Peter Smith, professor of history and associate dean of the graduate school at the University of Wisconsin, who is a leading scholar in a field where we had been looking for additional strength, Latin American studies. We welcome him to the Institute with great enthusiasm.

Professor Richard Cartwright assumed the burden of managing the complicated affairs of the Humanities Department during the whole of the academic year with characteristic grace and good humor. His old colleagues in the School Council were pleased to welcome him back and were once more sorry to see him go.

HAROLD J. HANHAM

TABLE I
Enrollment in Distribution Subjects: 1979-80

Field	# of Subjects	Year 1	Year 2	Year 3	Year 4 & 5	Graduate	Total MIT	Wellesley	Harvard	GRAND TOTAL	%
History of Art and Architecture	3	20	14	18	23	12	85	2	0	87	1.90%
Humanities:	68	1,180	792	627	590	37	3,209	14	3	3,226	70.44%
American Studies	1	2	6	3	8	0	15	4	0	19	.41%
Anthropology / Archaeology	4	49	37	30	37	0	153	0	0	153	3.34%
Foreign Languages	10	157	87	58	41	16	358	1	0	359	7.84%
History	13	147	113	111	88	2	458	3	0	461	10.07%
Literature A (English)	18	338	230	197	231	5	998	3	0	1,001	21.86%
Literature B (Foreign Language)	10	22	20	20	22	3	87	0	0	87	1.90%
Music	4	234	181	117	78	7	614	1	2	617	13.47%
Western Tradition	5	33	42	26	30	3	132	2	0	134	2.93%
Writing	3	198	76	65	55	1	394	0	1	395	8.62%
Linguistics	2	20	35	29	20	1	100	3	2	105	2.29%
Philosophy	6	200	107	68	66	0	439	2	0	441	9.63%
Political Science	8	99	80	87	73	3	330	12	0	342	7.47%
Science, Technology, and Society	7	40	47	41	46	3	176	0	1	177	3.86%
Urban Studies	5	13	28	33	40	3	112	5	0	117	2.55%
Visual Arts	2	16	53	9	7	0	85	0	0	85	1.86%
TOTAL	101	1,588	1,156	912	865	59	4,536	38	6	4,580	100.00%
%		34.7%	25.2%	19.9%	18.9%	1.3%	99.0%	.8%	.2%	100.0%	

Enrollment data are taken from the Registrar's fifth-week report.

TABLE II
Enrollment in Humanities, Arts and Social Sciences Elective Subjects: 1979-80

Field	# of Subjects					Total MIT	Wellesley	Harvard	GRAND TOTAL	%	
	Year 1	Year 2	Year 3	Year 4 & 5	Graduate						
Economics	27	340	521	454	326	63	1,704	10	8	1,722	25.77%
History of Art and Architecture	3	2	14	40	26	34	116	7	9	132	1.98%
Humanities:											
Anthropology/Archaeology and Literatures	21	59	61	68	81	5	274	3	2	279	4.17%
Foreign Languages	57	222	194	209	209	222	1,056	23	3	1,082	16.19%
History	16	8	57	71	73	1	210	3	3	216	3.23%
Interdisciplinary	18	6	32	38	43	12	131	14	7	152	2.27%
Literature	32	35	78	116	151	6	386	12	0	398	5.96%
Music	22	39	138	141	140	13	471	6	3	480	7.18%
Writing	21	71	60	97	109	21	358	9	6	373	5.58%
	<u>187</u>	<u>440</u>	<u>620</u>	<u>740</u>	<u>806</u>	<u>280</u>	<u>2,886</u>	<u>70</u>	<u>24</u>	<u>2,980</u>	<u>44.58%</u>
Linguistics and Philosophy	18	13	38	74	92	21	238	5	2	245	3.67%
Political Science	32	23	108	174	163	7	475	70	4	549	8.21%
Psychology	15	39	109	133	133	11	425	11	3	439	6.57%
Science, Technology, and Society	17	4	21	35	30	11	101	2	5	108	1.62%
Urban Studies	14	4	28	43	53	6	134	26	3	163	2.44%
Visual Arts	18	17	53	59	95	33	257	15	17	289	4.32%
Subjects in Other Schools	6	1	22	16	7	8	54	2	0	56	.84%
<u>TOTAL</u>	<u>337</u>	<u>883</u>	<u>1,534</u>	<u>1,768</u>	<u>1,731</u>	<u>474</u>	<u>6,390</u>	<u>218</u>	<u>75</u>	<u>6,683</u>	<u>100.00%</u>
Percent (%)		13.2%	23.0%	26.4%	26.0%	7.1%	95.6%	3.26%	1.1%	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>
	<u>1980</u>	<u>1981</u>	<u>1982</u>	<u>1983</u>	
American Studies	5	6	0	0	11
Ancient & Medieval Studies	5	2	2	0	9
Anthropology/Archaeology	8	5	5	0	18
Drama	9	11	4	0	24
Economics	249	99	23	1	372
Foreign Languages and Literatures	52	70	37	4	163
History	67	28	6	0	101
History of Art and Architecture	20	6	0	0	26
Labor in Industrial Society	0	0	0	0	0
Linguistics	10	3	0	1	14
Literature	99	46	14	0	159
Music	72	46	12	0	130
Philosophy	49	14	0	0	63
Political Science	115	44	11	2	172
Psychology	87	37	6	1	131
Russian Studies	7	2	1	0	10
Science, Technology, and Society	14	10	9	0	33
Urban Studies	4	5	2	0	11
Visual Arts and Design	34	8	2	0	44
Western Tradition	8	0	2	0	10
Writing	84	30	12	0	126
Special	<u>9</u>	<u>9</u>	<u>1</u>	<u>0</u>	<u>19</u>
TOTAL	1,007	481	149	9	1,646

Program in Science, Technology, and Society

The STS Program is now three years old, well into what we have been calling the "developmental phase" of the prospective College of Science, Technology, and Society. In fact there are growing signs of transition from a developmental mode toward a more "steady state" of operation. This year, for the first time, virtually the entire faculty of about 20 full- and part-time members were in residence; course offerings nearly doubled and undergraduate enrollments went up substantially; the level of faculty research increased, as measured both by publication of completed work and by the development of new research projects.

Awareness of the Program's presence has begun to grow within the Institute and in academic circles in the United States and abroad. The distribution this spring of a brochure describing the Program helped draw attention to the quality of our faculty and the strength of the Institute's commitment to our goals. During the past year we also became a cosponsor, with the Kennedy School of Government at Harvard, of the quarterly review, *Science, Technology, & Human Values*. We expect that the journal will serve as an important vehicle for bringing the social, intellectual, and educational concerns of STS to wider audiences.

However, these and other tangible signs that the Program is beginning to come of age should not obscure the magnitude of what remains to be done. We need to sharpen the definition of our goals and priorities, to create effective organizational frameworks within which to realize those goals, and to secure the necessary funds. Such developmental tasks as these will continue to demand the lion's share of our attention for some time to come. At the head of the priority list for next year are: 1) recommendations to the appropriate Institute faculty committees concerning undergraduate and graduate degree programs to be offered by the STS Program either independently or jointly with existing departments; 2) expansion of the volume and range of research carried out under the Program's auspices by its own core members, by faculty from other parts of the Institute, and by fellows, graduate students, and short-term researchers; and 3) proposals for training and study programs designed for professional people in a number of fields potentially involved in policy-related aspects of science and technology.

In all these contexts we continue to be conscious of the need for collaboration with colleagues elsewhere in the Institute who share some of our objectives and might welcome the chance to participate in some of our activities. Our new quarters at 70 Memorial Drive (Building E51), now firmly scheduled to be renovated and ready for occupation by the summer of 1981, should give greater opportunities to initiate cooperative ventures requiring space which we have lacked up to now. The building, which we will share with the Sloan School, will contain much-needed meeting facilities, as well as more adequate and flexible office and study space.

Educational Programs

Our educational efforts have continued to be directed primarily toward the development of the undergraduate curriculum. With the core faculty largely in place, we had our first opportunity to present students with a reasonably full range of STS subjects. Thirty-three students registered for a three-subject concentration in STS, in partial fulfillment of the Institute requirement in the Humanities, Arts, and Social Sciences.

We also have continued to develop degree programs for students interested in making the study of science, technology, and society a major part of their educational experience. As an experimental step in this direction, the Department of Humanities, with the particular assistance of faculty from STS, inaugurated this year a new version of the Humanities and Science and Humanities and Engineering majors in Course XXI for students interested in the social and cultural dimensions of science and technology. An initial group of 10 undergraduates enrolled in this option of Course XXI last fall, and a comparable number of new students is expected for 1980-81.

An ad hoc committee of STS faculty has been exploring other possible degree programs, including one intended to offer a new form of liberal education adapted to MIT's traditional emphasis on

science and technology and to the special skills and interests of its student body. We are also considering a variety of dual degree programs to be developed in collaboration with the School of Engineering and potentially with the School of Science. These would be designed to equip students with a double competence in the social study of science or technology and in a particular field of science or engineering. One possibility under discussion would involve a five-year course of study leading to a combined S.B./S.M. degree.

The Program also has begun to consider how it can best contribute to graduate education at MIT. We now offer graduate-level subjects jointly with a number of departments, and several students in the Department of Political Science have arranged to take one of their required fields of study in STS. The Program has received a steady stream of inquiries from prospective students interested in working toward the Ph.D., but we remain reluctant to embark on a full-scale doctoral program. Our present belief is that the needs of the few exceptionally qualified individuals who might reasonably be encouraged to seek doctorates in STS can best be served through the opportunities MIT offers for individually tailored doctoral programs under the supervision of ad hoc interdepartmental faculty committees. However, we are exploring the possibility of instituting a Master's program -- preferably in collaboration with Political Science -- that would offer a terminal, professional degree, to be taken in preparation for careers in industry or government involving policy-related issues concerning science and technology.

Lecture Series and Faculty Seminars

The Program helped organize two faculty seminars during the year. Together with the Center for International Studies, we sponsored a seminar series on "Risk, Technology, and Society" which attracted an average of 30 participants from MIT and Harvard. The topics addressed were carbon dioxide in the atmosphere, nuclear plant siting, depletion of the stratospheric ozone layer, and nitrite as a food additive. At each session a report was given on the state of scientific understanding of the issue, followed by general discussion of the risks involved and their implications for decision making. The seminar will continue next year, with the possibility that it may lead to development of a research project in this area.

A second faculty seminar, on the topic "Quality Indicators of Science," was initiated and organized by Professor Gerald Holton as part of a National Science Foundation-sponsored research project on the same theme. The seminar, attended by faculty members from Harvard and MIT along with government and foundation representatives, met four times during the spring. The sessions began with talks by Harvey Brooks, Robert S. Morison, Frank Press, and Kenneth Prewitt. The goal of the seminar and of the associated project is to suggest ways in which traditional assessments of science might be complemented and made more useful by measures which take into account other more qualitative dimensions.

This year, as last, a lecture series on "Technology and Work: The Perspective of Labor" was sponsored jointly with the Technology and Culture Seminar. Organized principally by Professor David F. Noble, the series gave interested Institute members an opportunity to hear the views of half a dozen highly articulate leaders of the labor movement on issues related to the impact of new technologies on the workplace.

The Program also inaugurated its own Colloquium Series this year under the leadership of Professor Merritt Roe Smith. Twelve lectures were given, primarily by outside speakers, on such topics as "The Regulation of Biomedical and Social Science Research" (Daniel Callahan, Director of the Hastings Institute), "Precolumbian Technology in the Andean World" (Professor Heather N. Lechtman); "Women, Science, and Mythology" (Evelyn Fox Keller, STS Research Fellow); and "The Rise and Decline of Development Economics" (Albert Hirschman, Institute for Advanced Study, Princeton). The Program also sponsored, jointly with the Anthropology-Archaeology Section of the Humanities Department, a series of talks by three leading anthropologists -- Professors Laura Nader, James Peacock, and Anthony Wallace -- all of whom have applied anthropological insights and methods to the study of industrial societies.

Research Fellows

A year ago the Program received a grant of \$500,000 from the Exxon Education Foundation for a program that will enable us to support four or five research fellows a year for the next five years.

Last fall the fellowship awards were widely publicized through journal advertising and direct mailing, resulting in the receipt of over 200 applications. After many hours reviewing curricula vitae and research proposals, a selection committee chaired by Professor Loren R. Graham decided to award five fellowships (two of them will be part-time) for 1980-81. The fellows chosen are Naomi Aronson, Assistant Professor of Sociology, Northwestern University ("The Social and Institutional Context of Nutrition Research: The Case of Vitamin A"); Barry M. Casper, Professor of Physics, Carleton College ("Politics and Values in Energy Policymaking"); Gilbert W. Moore, Consultant on Community Economic Development, Greater Boston Area ("Appropriate Energy Technologies for Depressed Communities"); Harley Shaiken, Consultant on Labor Affairs, United Auto Workers Ford National Negotiating Committee, Detroit ("Computer-Based Technologies and Their Social Impact"); and Rosalind H. Williams, European Historian, Newton, Mass. ("Proposals for 'Appropriate Technology' by Late Nineteenth-Century Anarchists").

During the past year, two research fellows were in residence, supported by funds from earlier grants. Dr. Janet M. Corpus, who recently received her Ph.D. from the Department of Urban Studies and Planning, has been studying social policy issues relating to employment and the labor force. Dr. Keller, Associate Professor of Mathematics at the State University of New York, Purchase, has been pursuing studies on the personal and psychological orientations of scientists, especially women scientists, in relation to their scientific work. Dr. Keller plans to remain at the Institute for a second year to undertake a study, based in part on interviews with women science and engineering students at MIT, of the ethical and value implications of the present influx of women into the scientific and technological work force.

RESEARCH

Current faculty research can be summarized under three broad headings: 1) history and social study of science, 2) technology and the organization of industrial societies, and 3) cultural systems in industrial societies.

History and Social Study of Science

A substantial amount of research has been or is about to be published on topics in the history of science. Receiving much favorable attention upon its publication by the Harvard University Press was *Robert Oppenheimer: Letters and Recollections*, edited and annotated by Dr. Alice Kimball Smith and Professor Charles Weiner. Also published this spring by Cambridge University Press was Dr. Peter Buck's *American Science and Modern China*, a study of the transmission of scientific ideas and organizations from the United States to China which sheds fresh light on the social history of late nineteenth- and early twentieth-century American science.

Another recently completed manuscript, now being readied for publication by Columbia University Press, is Professor Graham's "Between Science and Values: Expansionism and Restrictionism in Modern Science." The book is based on case studies from twentieth-century physics and biology which focus on the ways in which scientists in different societies have dealt with the linkages between their scientific work and important social and political value issues. Professor Graham also has published several articles about Soviet science and Soviet-American scientific relations, fields in which he has had a long-standing interest. Mention also should be made of the forthcoming publication by the Reidel Press of a study written by Professor Louis L. Bucciarelli in collaboration with Nancy Dworsky entitled "Sophie Germain, An Essay in the History of the Theory of Elasticity."

Professor Kenneth R. Manning has continued his research on the role of blacks in American science. He is writing a full-scale biography of the black scientist E. E. Just (1883-1941), who did pioneering work on cell biology. Professor Manning was promoted to Associate Professor this year and was also honored by being named Class of 1922 Career Development Professor for the next two years.

An account of the Program's work in the history of science would be incomplete without reference to the contributions of two prominent senior historians of science whom we are fortunate to have

with the Program on a part-time basis: Professor Holton and Professor Thomas S. Kuhn. Professor Kuhn, who has a joint appointment with the Department of Linguistics and Philosophy, is focusing on questions in the philosophy of language which bear on the philosophy of science, and on questions concerning the nature of cognitive processes. Professor Holton, one of the Program's founding members, holds a visiting appointment at MIT while maintaining his long association with Harvard University. Last year he completed a large number of articles on aspects of the history of modern physics, especially relating to the contributions of Albert Einstein.

Research is also proceeding on controversial, contemporary issues of public policy in which scientific and technical questions loom large. For some time Professor Joel Yellin has been studying issues involving scientific uncertainty and risk, especially the ways in which the judicial system in this country has dealt with major environmental questions. This year he completed two lengthy articles -- one on "Nuclear Power and the Supreme Court: Risk, Rationality, and Technological Change," and the other (with Professor Paul Joskow) on "Siting Nuclear Reactors." Professor Yellin currently is writing a book on legal institutions and technological change. Professor Weiner will be on sabbatical leave next year working on two projects of contemporary concern, a book on the history and social impact of recombinant DNA research and other recent developments in biology, and a series of biographical studies based on oral history interviews of leading American physicists and biologists. Dr. Robert S. Morison has continued with his reflections on modern medical technology and its cultural implication. His paper, "A Further Note on Visions," published in the winter issue of *Daedalus*, explored some of the reasons why modern scientists find it so difficult to deal with the question, "What is all your technology for?"

Technology and the Organization of Industrial Societies

A variety of studies, both historical and contemporary, are continuing in this area. Professor Merritt Roe Smith, whose special field is the history of eighteenth- and nineteenth-century industrial technology, is at work on a book tentatively entitled "Mechanizing America," a survey of the interactions of American technology and culture in the nineteenth century. He also is developing a major new study, with contemporary as well as historical dimensions, which will examine the role of the military in industrial and technological change. Professor Noble is nearing completion of a book which will explore the development of new technologies and their impact on labor; it will deal in particular with the social history of the design and use of automated machine tools in US industry.

Professors Kenneth Keniston and Leon Trilling are investigating aspects of the selection, training, and career patterns of professionals with "elite" engineering training in the United States and France. Professor Keniston divided his time this year between Cambridge and Paris while holding a Guggenheim Fellowship, interviewing engineering students and exploring in other ways the claim that industrial societies tend to produce a common "technocratic" value orientation toward problem solving. Professor Trilling has been concentrating on comparative analyses of educational and career patterns among engineers in the United States and France; some of the results of his work appeared this spring in *Minerva*.

Professor Charles Sable, whose current research has focused on the politics and sociology of work and the labor movement, has delivered to the Cambridge University Press the revised version of his book on industrial conflict and the sociology of the labor market. This book, as well as several articles published during the year, combines theoretical work in political economy with empirical studies of industrial work conducted in Germany, Italy, and the United States.

The Program's ability to carry out its commitment to comparative study of advanced industrial societies has been enhanced by the recent addition of two faculty members. Dr. Carl Kaysen, David W. Skinner Professor of Political Economy, joined us during the spring term when he returned from leave as Director of the Sloan Commission on Government and Higher Education. The Commission's Report, *A Program for Renewed Partnership*, appeared late in the spring. Professor Kaysen has written on government regulation of business, on various economic topics, on higher education, and on the sociology of business. Also joining the STS Program, on a half-time basis for the present, is Professor Emma Rothschild, who came to MIT two years ago as Director of the Writing Program. Professor Rothschild's wide-ranging interests include the automobile and energy industries, armaments issues, and the world food economy. She is a member of the Organization

for Economic Cooperation and Development's "Expert Group on Science and Technology in the New Socioeconomic Context" and a co-author of the group's recently issued report.

Cultural Systems in Industrial Societies

This part of our research program aims to clarify the role of ideologies and belief patterns in shaping the interactions of science and technology with other aspects of contemporary life. Professor Leo Marx is working on a book about American "pastoralism" as a modern ideology which is, in his view, partly a reaction to the scale and complexity of industrial society. Professor Sherry R. Turkle is exploring, through an ethnographic study of computational cultures and subcultures, the social and psychological factors which influence how people relate to computers. Her earlier book, *Psychoanalytic Politics: Freud's French Revolution*, has received many favorable reviews and will be appearing in a French edition next fall. It is a pleasure to report Professor Turkle's promotion to associate professor this year.

DONALD L. M. BLACKMER

Department of Economics

The Decade Just Completed

Despite the many cross currents that have affected the country and the student body, the Department has made steady growth over the past 10 years in many areas. While the 21 Bachelors of Science in Economics awarded this academic year were the fewest in more than a decade (20 percent below the decade average) enrollments were substantially larger. In the two introductory subjects, 14.01 and 14.02, enrollments were 50 percent higher than in 1971, and more than 10 percent higher than the highest previous year of 1977. Enrollments in the more advanced subjects have followed this approximate pattern.

The number of Doctors of Philosophy awarded in Economics, on the other hand, has grown somewhat. In the decade of the 1960s, 19.5 Ph.D.s were awarded. In the first half of the '70s the number rose slightly to 20.4, and in the five years ending with this year, the average has risen to 26.6. These larger numbers are primarily attributable to higher completion rates, although the earlier rates were high by most standards. Moreover, placement of these graduates has not been a problem: the high quality of our students has resulted in a continuing large demand for them in universities; and their training has placed them in great demand in consulting firms, business organizations, and government agencies, where demand continues to expand.

The faculty also has expanded over this decade, something over 20 percent, partly to meet the increased enrollments, but also in anticipation of a large number of potential retirements among the faculty.

The Minority Ph.D. Program after a Decade

A minority program was instituted by the Department a decade ago, under which a flexible position was adopted with respect to the course load of minority students, special tutoring was provided before the entering year, and academic support groups were available throughout the years of course work when needed. Over this period of time, 27 minority applicants were admitted to the program. Two-thirds, or 18, passed the general examinations, while nine withdrew before taking them. Seven completed their theses and were awarded degrees, six are still registered for dissertation research, and the remaining five withdrew before completion of their dissertations. The entering class this year will contain three minority students -- a black, an American Indian, and a Puerto Rican -- two of whom will have NSF minority fellowships.

While minority students have had considerable success in finishing their course work and examinations, we need to improve the rate at which dissertations are completed. Two additional major problems affect the program. The number of applicants from minority groups has not increased over the decade; indeed, it is smaller now than at the beginning of the program, although the quality has increased. Since our program has represented a significant percentage of the national total, we conclude that professional programs in, for example, law and business, have justifiably been more attractive to the able minority student.

The 50th Anniversary of the Stock Market Crash of 1929

The Graduate Students Association maintained their tradition of timely special programs by sponsoring a celebration of the stock market crash of 1929. A distinguished panel consisting of Professor James Tobin and Ray Fair of Yale University along with Institute Professor Franco Modigliani and Professor Robert Pindyck discussed the state of the economy in an afternoon session. A no less distinguished, but less reverent, group -- Professor J. K. Galbraith of Harvard; Paul Erdman, author; Institute Professors Paul A. Samuelson and Robert M. Solow; and Ford Professor Emeritus Charles P. Kindleberger -- analyzed the 1929 crash. This well-organized event was the major responsibility of graduate students Rhonda Williams and Jeff Dubin.

Honors and Recognition

A large number of faculty have been given unusual recognition this year. Institute Professor Solow completes his terms as president of the American Economic Association; Professor Franklin M. Fisher also retires as president of the Econometric Society; Institute Professor Modigliani is vice president of the International Economic Association and vice president and president-elect of the American Finance Association; and Professor Morris A. Adelman has been elected president of the International Association of Energy Economists.

Professor Rudiger Dornbusch has become a Fellow of the American Academy of Arts and Sciences; Professor Jeffrey E. Harris has been elected to the New York Academy of Science; and Institute Professor Solow has been elected to the American Philosophical Society.

Professor Peter A. Diamond will receive the Mahalanobis Medal given by the Indian Econometric Society every four years to the outstanding international econometrician under 45 years of age; Professor Jerry A. Hausman is the recipient of the Ragnar Frisch Award given by the Econometric Society every two years for the outstanding paper published in *Econometrica*; Professor Emeritus Kindleberger has been elected Distinguished Fellow of the American Economic Association; Professor Harris has been granted a five-year career-development award by the National Institutes of Health; Professor Eric S. Maskin is the recipient of a Guggenheim Fellowship for the coming year; Professor Daniel L. McFadden gave the Irving-Fisher-Henry-Schultz Lecture to the Econometric Society; and Institute Professor Modigliani received the Graham and Dodd Award for the best paper in finance given by the Financial Analysts' Federation, and a Doctor Honoris Causa in Economics and Commerce from the Instituto Universitario di Bergamo.

Joseph E. Stiglitz, who received his doctorate from us in 1965, was the recipient of the John Bates Clark Medal given every two years by the American Economic Association to the outstanding American scholar under 40 years of age. Barry Nalebuff, who graduated with degrees in both economics and mathematics this year, was winner of a Rhodes Scholarship.

FACULTY

Many faculty were on leave this year: Professor Richard S. Eckaus was on sabbatical for the spring term; Professor Michael J. Piore was away for the whole year on sabbatical and with a Ford grant to study comparative labor markets in the United States and France; Professor Dornbusch was on a Guggenheim Fellowship in Brazil; Professor Paul L. Joskow spent the year at the Kennedy Institute studying regulatory problems; Professor Stanley Fischer was on research leave for the fall term; and Professor Lester S. Thurow spent the fall term as editorial writer for *The New York Times* and the spring term at the University of Arizona.

To fill some of the gaps left, two new assistant professors -- Robert C. Litterman of Minnesota and Lawrence H. Summers of Harvard -- were appointed; and Instructor Joseph v.R. Farrell of Oxford. In addition, we were assisted by Visiting Professors Christopher Sims of the University of Minnesota and John Williamson of the Catholic University of Brazil.

Professors Harris and Maskin were promoted from assistant to associate professors. Dr. Timothy J. Kehoe, who received his degree from Yale University, will come here as an assistant professor from Wesleyan University.

Professor Jagdish Bhagwati will resign this year to accept a professorship at Columbia University. It will mean a heavy professional and personal loss to the Department. Professor Bhagwati came here with a very broad and intensive training: at Cambridge, Oxford, Chicago, and MIT. He was a Professor of the Indian Statistical Institute for a year and then Professor of International Trade at Delhi University from 1963-68, a major member of that remarkable group of young economists which included Amartya Sen, Sukhumoy Chakravarty, and T. N. Srinivasan. From there he came to MIT, after a year as visiting professor at Columbia University, with an established and growing reputation in the fields of international trade and economic development. As a member of our Department he has been enormously productive, publishing a vast number of articles in the major professional journals, many books on international trade and development, editor of the *Journal of International Economics* since its inception, a much sought after lecturer, a leader of a major research effort by the National Bureau of Economic Research on the impact of various foreign trade regimes on economic development. He was always sensitive to the problems and needs of the third world and concerned with such problems as potential brain drains. He was a popular and enthusiastic teacher, had many students to advise and counsel in their dissertation research, and was a cooperative and congenial colleague. We shall miss him sorely.

The other sad note on which I must end is the retirement of Professor Emeritus Harold A. Freeman. He has been at the Institute longer than anyone can remember or believe, coming here in 1927 as a freshman. He received his bachelor's degree in mathematics in 1931, and worked his way up from research assistant to Professor Davis R. Dewey (then Head of the Department and Editor of the *American Economic Review*) to Professor of Statistics. He was an early leader in the field of quality control, a member of that talented wartime group of Wallis, Mosteller, Friedman, and Wald, who developed sequential sampling. In later years he has been more concerned with design and analysis of experiments and time-dependent probability. Fortunately, Harold will continue to come to his office and to carry on his creative work; but we will miss his sage counsel and active participation in faculty meetings, and students will unhappily miss his superb teaching.

E. CARY BROWN

Department of Humanities

A year ago the future of the Department of Humanities seemed sufficiently uncertain that Professor Bruce Mazlish, then Head of the Department, stated that "there is a high probability that the Department of Humanities, as we have known it, will cease to be" (*Report of the President and the Chancellor*, 1978-79, p. 259). The Committee on the Reorganization of the Humanities (Professor Samuel Jay Keyser, chairman; Professors Richard Cartwright, Kenneth Keniston, Pauline Maier, and Mary Potter, members) had recommended that the Department of Humanities be abolished; that the History and Literature sections and the Foreign Languages and Literatures section together with the Writing Program be established as two separate departments; and that the programs in Anthropology/Archaeology and in Music be placed under the office of the Dean of the School of Humanities and Social Science. Although the Committee's recommendation was not universally welcomed within the Department, sentiment for it or some alternative form of reorganization was strong.

The Committee's report stressed the Department's disciplinary multiplicity, the growth of professional standards within the various sections, and the need for a structure that would nourish the sense of sectional identity the Committee saw as necessary to achieve and sustain academic

excellence. The Committee therefore recommended that, within its proposed structure, there be a large measure of sectional independence. In the end it was this recommendation that was adopted. Departmental and administrative discussion following upon the Committee's report concluded that the required measure of sectional independence could be achieved within the familiar departmental structure.

A search therefore began for a permanent replacement for Professor Mazlish as head of the Department. Dean Harold Hanham appointed a search committee consisting of Associate Dean Donald L. M. Blackmer, Professors Keyser and Cartwright, and -- in their capacities as section heads -- Professors Maier, Martin Diskin, Stephen Erdely, Margery Resnick, Emma Rothschild, and Irene Tayler. After reviewing some 200 applications the committee unanimously recommended the appointment of Peter Smith, professor of history at the University of Wisconsin's Madison campus. The recommendation met with administrative approval, and Professor Smith will assume the position of Associate Dean for Humanities Programs and Head of the Department of Humanities in July 1980.

Professor Smith is a distinguished scholar of political change in 20th century Latin America. He is the author of *Politics and Beef in Argentina: Patterns of Conflict and Change* (1969), *Argentina and the Failure of Democracy: Conflict among Political Elites, 1904-1955* (1974), and *Labyrinths of Power: Political Recruitment in Twentieth-Century Mexico* (1979). Professor Smith has been active as an administrator as well as a scholar. He is president-designate of the Latin American Studies Association. At the University of Wisconsin, where he has been a member of the History Department since 1968, he has served as Associate Dean of the Graduate School, Chairman of the Department of History, and Chairman of the Ibero-American Studies Program.

Professor Smith joins a department different in a number of ways from the one I first knew 13 years ago. The Philosophy Section seceded nearly a decade ago, a loss still felt by some members of the Department. But there have been significant additions. The Department now includes a large and active Foreign Languages and Literatures Section, under the energetic leadership of Professor Resnick. The Writing Program is another relatively recent addition; under Professor Rothschild's guidance it has moved in directions promising much for its future as an integral part of education at MIT. Less immediately obvious, but most impressive, is the heightened intellectual vitality of the Department: scholarly and artistic activities are vigorously pursued; recent appointments meet the highest standards; concern for the quality of undergraduate education is deep. The Keyser Committee was surely right in stressing the healthy professionalism that now exists in the Department.

Section reports document this in some detail. Let me single out certain items for special mention. In recognition of her international reputation as a student of ancient Andean civilization, as well as her dedicated direction of the MIT Center for Materials Research in Archaeology and Ethnology, Professor Heather Lechtman was promoted to full professor. Professor John Harbison was similarly promoted; and, as if in testimony to the wisdom of that act, he shortly thereafter received a commission from the Boston Symphony Orchestra for a major orchestral work. Professor Tayler was honored by a three-year appointment to MIT's newly established Thomas P. Meloy Professorship of Rhetoric. Professor Marcus Thompson won first prize in the National Black Music Colloquium, sponsored by the National Music Council and the Kennedy Center. Professor Julia Alissandratos received a grant for the coming semester from the International Research and Exchange Board to study medieval Slavic manuscripts in the Union of Soviet Socialist Republics. Professor Rothschild was a member of the group of experts on science and technology in the new socioeconomic context, under the Organization for Economic Cooperation and Development and she also served on UNESCO's panel of counsellors in long-term studies.

The performing arts flourished, in spite of the problems resulting from the sudden closing of Kresge Auditorium. Professor Harbison's opera, *Full Moon in March*, was staged in John Hancock Hall, with generous support from the Abramowitz Memorial Fund. The Dramashop presented *The Misanthrope* at the Loeb Theatre and *Man and Superman* at the Hasty Pudding Club. The newly organized Spring Arts Festival, jointly sponsored by the Department and MIT's Council for the Arts, was held in Hayden Courtyard.

Under the continued good auspices of the Friends of the Humanities, individual sections held lectures and seminars. Among the many notable speakers were Jorge Luis Borges, Ronald Blythe, Edwin Reischauer, Toni Morrison, and Helen Vendler.

With a sense of loss shared by all members of the Department, I report the death of Professor Joseph Everingham. From 1954 he served the Institute well as Director of Drama, in his quiet way instilling in hosts of students an appreciation of theatrical arts.

To the faculty and staff of the Department I express my very great thanks for their generous cooperation throughout the year. I am especially grateful to Professor Maier, for her assistance as Acting Associate Head, and to the other heads of sections, for their willing acceptance of burdens they had no reason to anticipate.

RICHARD L. CARTWRIGHT

ANTHROPOLOGY/ARCHAEOLOGY PROGRAM

During the past year the Anthropology/Archaeology Program curriculum was revised to reflect more general social and cultural concerns. Four new Humanities Distribution subjects have been approved: 21.513 Religious Movements and Social Change; 21.542 Culture and Visual Arts; 21.581 The Family in Contemporary Society; and 21.584 Agrarian Societies.

Professor Diskin served on the Humanities, Arts, and Social Sciences Requirement Committee, the committee of section heads that drafted recommendations for changing the structure of the Humanities Department, the search committee for Associate Dean for Humanities Programs, the committee to study the position of lecturers in the Writing Program, and the committee on minority recruitment in the Humanities Department. He was a speaker at the annual meeting of the Society for Applied Anthropology in Denver in March 1980. He published an article on Central America in *The Boston Globe* in August 1979. Professor Diskin was named a member of the Joint Committee on Latin American and Caribbean Studies of the American Council of Learned Societies and of the Social Science Research Council. His Mexican village demographic research is proceeding on schedule, and the first manuscript paper has been prepared.

Professor James Howe devoted the academic year to finishing a book on politics among the Cuna of Panama and to coauthoring a report on the status of the Indians of Paraguay. In April he delivered a paper on Cuna kinship at a symposium in Panama, and in the same month the Panamanian national university press brought out a book, *Cantos y Oraciones del Congreso Cuna*, of which he was chief editor.

Professor Jean Jackson published a review of E. Fisher's *Women's Creation in Sojourner*, September 1979, and an article, "Instant Underdevelopment for Colombia's Indians," in *Akwesasne Notes*, fall 1979. Professor Jackson finished a book manuscript presently under consideration by Cambridge University Press; she has begun research on a book concerning sex roles, especially the changes in female status caused by industrialization. She served on the Committee on Curricula and on the Corporation Joint Advisory Committee.

Professor Lechtman continued as director of the Center for Materials Research in Archaeology and Ethnology. The Center received two generous grants to purchase additional equipment for its Graduate Teaching Laboratory, one from the Anthropology Program of the National Science Foundation and the other from the Samuel H. Kress Foundation. Professor Lechtman also was invited to join the nine-member advisory committee of anthropologists and archaeologists to Public Broadcasting Associates, the television company producing the *Odyssey* series for public TV. She played a major role as consultant to *Odyssey's* film on the Inca, aired in May 1980. Professor Lechtman's publications for the year include: "Issues in Andean Metallurgy," in *Pre-Columbian Metallurgy of South America*, Elizabeth P. Benson, ed., Washington, D.C., Dumbarton Oaks: 1-40 and "A Pre-Columbian Technique for Electrochemical Replacement Plating of Gold and Silver on Objects of Copper," *Journal of Metals*, 31: 154-160.

Professor Wilma Wetterstrom returned to teaching duties at MIT after a year's leave of absence devoted to research on early agriculture in Egypt. In September she presented a paper on the preliminary results of this work, "Plant Remains from Predynastic Villages in Upper Egypt," at the Second International Congress of Egyptologists held in Grenoble, France. *The Bulletin de*

l'Association International Pour l'Etude de l'Egypte Prehistorique will soon be publishing a paper on this research, "Early Agriculture in Upper Egypt: A Note on Paleoethnobotanical Studies at Predynastic Sites in the Nagada Area." In January Professor Wetterstrom returned to Egypt to work with a team from the Oriental Institute of the University of Chicago excavating an ancient seaport on the Red Sea. She is presently analyzing plant materials from the site in order to determine the diet of the site's inhabitants. In keeping with her research interests in Egypt, Professor Wetterstrom taught a new course in the spring term titled "The Origins of Civilization in Egypt."

MARTIN DISKIN

HISTORY SECTION

The appointment of Professor Peter Smith as the new Associate Dean for Humanities Programs and Head of the Department of Humanities was one of several developments in 1980-81 that promise to strengthen the History Section's faculty in years to come. Professor Smith is a well-known scholar in Latin American history, a field taught by no present member of the Section's teaching staff. Another deficiency in the Section's current curriculum, East Asian history, was also remedied in the past year with the appointment of Peter C. Perdue, a Harvard doctoral candidate in Chinese history. In addition Professor Merritt Roe Smith, a historian of technology with a joint appointment in History and in the Program in Science, Technology, and Society, became an active member of the Section during the course of the past year; and Professor Loren Graham, a Russian historian and a specialist in the history of science who recently left the Department of History at Columbia University to join the Program in Science, Technology, and Society at MIT, accepted a joint appointment in the History Section. These additions will have a dramatic effect on the Section in terms of both size and professional visibility.

Professor Alan Brinkley was awarded both an Old Dominion and American Council of Learned Societies grant for 1980-81. His absence, along with the unexpected resignation of Professor Monroe Little, threatened to weaken seriously the Section's offerings in American History during the next academic year. The Section was fortunate, however, in appointing Professor Michael Les Benedict of Ohio State University as visiting professor for the spring term of 1981; he has published widely in the history of Reconstruction and American constitutional history. Gary Kornblith, a Princeton doctoral candidate who this past year assisted in Professor Brinkley's popular subject on America since World War II, will continue at MIT as an instructor, part-time, assuming primary responsibility for the subject on recent American history and also for another on the early national period.

Professor Thomas Mahoney will continue on leave during 1980-81, but the Section will benefit from the return to active teaching of Professor Mazlish and from the return of Professor David Ralston, who has taught at the Naval War College in Newport, Rhode Island, over the past three years.

Preparatory to its search for an East Asian historian, the Section sponsored a series of lectures during the spring term on "New Directions in Asian History." The series began on February 28 with a well-attended lecture on Japan by Harvard University's Professor Edwin O. Reischauer; on March 13 Professor Benjamin I. Schwartz, also of Harvard University, spoke on China; and on March 20 Professor John McLane of Northwestern University discussed Indian history. During February and March the Section also sponsored a series of film documentaries on South Asia.

The Section continued the effort, begun in academic year 1978-79, to revamp its subject listings. Categories of subjects have been redefined; several subjects have been excised from the list; and descriptions have been revised to reflect more accurately subjects' contents. The revision will continue next year, with an examination particularly of offerings in European history.

Members of the Department contributed to many activities within the Department and the Institute: Professor Arthur Kaledin served as a freshman advisor and a member of the Committee on Discipline; Professor Maier, who was Acting Associate Head of the Department of Humanities during

1979-80, was a member of the search committee for an Associate Dean for Humanities Programs and Head of the Department of Humanities, and served as chairman of committees to consider the promotion of Professors Harbison and Lechtman to the rank of full professor and of another committee on the position of lecturers in the Writing Program.

Section members were also active participants in a number of professional conferences: Professor Maier in the Southern Historical Association; Professor Robert Rotberg in the Ditchley Foundation's Conference on Southern Africa; Professor Kaledin in the American Political Science Association; Professor Mazlish in the San Francisco International Psychiatric Symposium and a conference on the Psychohistorical Meaning of Leadership. Professor Rotberg was local chairman for the Social Science History Association's 1979 meeting in Cambridge. Section members served as consultants or panel members: Professor Maier for the National Endowment for the Humanities, the American Council of Learned Societies, the University of Pennsylvania Press, and the University of North Carolina Press; Professor Kaledin for the Essex Institute in Salem; Professor Mazlish for Basic Books. Members of the Section on editorial boards included: Professor Maier on *Reviews in American History*; Professor Rotberg on the *Journal of Interdisciplinary History* (which he continues to edit); Professor Mazlish on the *Journal of Family History*, *The Psychohistory Review*, and *Political Psychology*. Professor Maier gave the annual address at the South Carolina Historical Association meeting in Charleston and the Helen G. Stafford Memorial Address at the University of Richmond; Professor Kaledin spoke at a colloquium on 19th century French Studies at the University of Pennsylvania; Professor Rotberg addressed the World Affairs Council of Boston on the subject of South Africa and gave a Hamilton Hall Lecture in Salem; and Professor Mazlish presented lectures at the University of Pennsylvania, Pennsylvania State University, Moravian College, Lehigh University, Drexel University, and Carnegie-Mellon University. Professor Maier is a member of the Organization of American Historians' Executive Committee. Professor Mahoney is on the United States Department of Education's Ethnic Heritage Committee, and he will continue as Secretary of the Department of Elder Affairs, Commonwealth of Massachusetts.

Publications for the year include Professor Mazlish's *Jimmy Carter: A Character Portrait* (with Edwin Diamond; New York, 1979) and "The Hysterical Personality," in the *Journal of Interdisciplinary History*, Vol. XI (1980); Professor Harald Reiche's "The Language of Archaic Astronomy, A Clue to the Atlantis Myth?" in Brecher and Feirtag, eds., *Astronomy of the Ancients* (Cambridge, 1979), which will be issued in paperback during 1980; Professor Rotberg's "Creating a More Harmonious South Africa," in Rotberg and John Barratt, eds., *Conflict and Compromise in South Africa* (Lexington, Mass., 1980), and his *Suffer the Future: Policy Choices in Southern Africa* (Cambridge, 1980). Professor Maier completed work on *The Old Revolutionaries: Political Lives in the Age of Samuel Adams*, which will be published by Alfred A. Knopf in New York during September 1980.

PAULINE MAIER

FOREIGN LANGUAGES AND LITERATURES SECTION

During the past year the faculty and staff in the Foreign Languages and Literatures Section have worked extensively in four major areas: curricular innovation, faculty development, participation in Institute activities, and establishment of a leadership role in our field through scholarly activities and sponsorship of programs which have drawn the attention of the academic community.

Curricular Innovation

The training and expertise of our new faculty members in Spanish, Professor Elizabeth Garrels and Instructor Gladys Varona-Lacey, made possible a full complement of Spanish language, literature, and civilization subjects which cover all major areas of the Peninsular Spanish and Latin American fields. There was, in addition, a noticeable increase in extracurricular activities in Spanish. Spanish House was opened in September 1979 and supported a variety of Hispanic cultural programs.

Significant curricular changes have been effected in our program in English as a Foreign Language. A new sequence of 11 subjects designed to meet the special needs of MIT's foreign students has been instituted. The implementation of an Institute-wide testing program allowed us to collect data on each incoming foreign graduate student and forward it to advisors before the semester began, thus allowing them to advise foreign graduate students more effectively. Departments report a significant improvement in advising and a measurable improvement in English skills as a result of this program. We have been asked by the Undergraduate Academic Support Office to establish a similar evaluation program for incoming freshmen. Such a test will be given in fall 1980.

The skill of our new language laboratory director, Ruth Trometer, has helped us exploit the full capabilities of the lab. This year's improvements include the organization of a cross-reference tape catalogue system, a script file, a system for codifying master tapes, and the publication of a procedures manual for students and faculty. The hiring of an in-house laboratory technician has enabled us to keep the lab in excellent repair, and has given us technical expertise in our production of live recordings, selection of equipment, and training of student staff.

Our standard curricular offerings were enriched by the Section's sponsorship of 23 activities during the Independent Activities Period (IAP).

Faculty Development

During this year we conducted two faculty searches: one in French and one in German. In the first we sought an Assistant Professor of French with a specialty in the 18th century. Janie Vanpée, who is currently completing her Ph.D. at Yale University, was appointed. The German search was necessitated by the departure of Lecturer Ilse Evans. The candidate selected was Edith Waldstein, who is completing her Ph.D. at Washington University and whose major field is the German 19th century. We also conducted searches to replace the many part-time staff members in Spanish and French with full-time lecturers who will contribute to the ongoing activities of the Section. Gilberte Furstenberg in French, and Douglas Morgenstern in Spanish, will be joining us next year in this capacity.

In the fall, Professor Isabelle de Courtivron was promoted from assistant to associate professor of French. In the spring, there were nine faculty and staff members whose scholarship, teaching, and service were reviewed for reappointment. The procedures followed for these reappointments were established by the Section during the fall semester, and while the process proved to be extremely time-consuming, it is hoped that the feedback received by each individual will help in career planning.

MIT Activities of Faculty and Staff

The faculty and staff of Foreign Languages and Literatures have served the Department and the Institute in a variety of ways. Senior Lecturer Claire Kramsch served on the Humanities, Arts, and Social Sciences Committee and the Department's committee on minority recruitment; Professor Catherine Chvany on the IAP Committee; Professor Robert Jones on the Committee on Foreign Scholarships; Professor Resnick as housemaster of McCormick Hall, member of the Committee on Educational Policy, and member of the Ad Hoc Committee on Women's Admissions. Professor Resnick was also named to the new Women's Advisory Committee and was elected president of MIT's chapter of Phi Beta Kappa. Fourteen members of the Section are freshman advisors. Finally, all members of the Section worked closely with our four language houses to help them develop cultural programs.

Community Activities

Members of the Section have worked to establish productive relationships with the public school system in Massachusetts. Senior Lecturer Kramsch organized a German exchange with local high schools in which MIT students visited high school German classes and then reciprocated by being hosts at the Institute. In addition Senior Lecturer Kramsch was awarded a grant which allowed her to conduct a "total immersion" project in German at MIT for the second time this June. This project brought high school students and teachers from the state to an intensive German program

housed in McCormick Hall. Lecturer Evans conducted a workshop on the teaching of intermediate German which drew participants from the entire Boston area. Professor Chvany served as a judge in the State Olympiada of high school Russian. Professor Resnick helped establish the Consortium of Chairmen of University Foreign Language Departments in the Boston area for which she serves as executive director. This group sponsored a number of meetings with chairpersons of high school foreign language departments to discuss articulation of the curriculum between high schools and colleges, the establishment of a resource exchange for junior year abroad programs, and a jointly supported foreign film festival for next year.

Members of the Section worked together on a series, "The Political Role of the Intellectual in 20th-Century Western Society," for which the following colloquia were organized: Dominique Desanti, historian and journalist for *Le Monde*, "L'Intellectuel et L'engagement Politique: 1920-1980; Résistance et Collaboration"; Dr. Jaime Giordano, Professor of Spanish at the State University of New York at Stony Brook, "Pablo Neruda, Poet and Politician"; Dr. Helga Pross, German scholar, "Sex Roles: The Position and Consciousness of Women and Men in Western Europe"; Yanquetruz, an Argentine exile, "Political Poetry and Songs of Latin America"; Peter Lilienthal and Michael Rubbo, "German and French Directors Confront the Politics of Contemporary European Filmmaking"; and a panel discussion, "Focus on Nicaragua and Central America." In addition, two plays in Spanish by Valle-Inclán were performed, and Jorge Luis Borges addressed an audience of approximately 1,000 people at the Institute. Large numbers of colleagues and students also enjoyed the Russian mime, Boris Amaratov; a lecture by Anatoly Lieberman on Lermontov; and a series on the New German Cinema, cosponsored by MIT and the Goethe Institute. A panel discussion "The Audible Curriculum -- A Cross-Cultural View of University Lecture Styles" rounded out this year's programs.

Participation in Professional Organizations

Several members of the Section held leadership roles in scholarly organizations this year. Professor Chvany is on the executive committee of the Modern Language Association Slavic linguistics group, on the executive board for the American Council of Teachers of Russian, and vice president of the American Association of Teachers of Slavic and East European Languages; Professor Martin Dyck is a member of the Delegate Assembly of the Modern Language Association; Professor Garrels, rapporteur at the Woodrow Wilson Center for Latin American Studies on "The Rise of the New Latin American Narrative"; Senior Lecturer Kramsch, president of the American Association of Teachers of German; Instructor Katherine Paszkolovits, vice president of the American Association of Teachers of German; Professor Resnick, director of the Modern Language Association bibliographical project, "International Women Writers in Translation," and a board member of the International Institute of Spain.

Scholarly Activities

The level of scholarly activity in the Section was high this year. Thus, 16 members of the Section presented papers at a total of 28 national and international meetings. In addition, members of the Section were invited speakers at a number of other institutions. Talks were delivered by Professor Alissandratos at Yale University; Professor Chvany at Harvard University; Lecturer Kathy Irving at Tufts University; Senior Lecturer Kramsch at Wellesley College, Middlebury College, and Tufts University; Instructor Paszkolovits at the University of Connecticut; Professor Resnick at City University of New York, Harvard University, Phillips Andover Academy, and Colorado College; Professor Edward Turk at Harvard University.

During this year two books were published by faculty members in Foreign Languages and Literatures: Professor de Courtivron's *New French Feminisms*, coedited with Elaine Marks, University of Massachusetts Press; and Professor Garrels's edition of *Siete Ensayos de Interpretación de la realidad peruana*, Biblioteca Ayacucho, Caracas.

In addition to book reviews and essays accepted for future publication, the following articles by members of the Section appeared during the year: Professor Chvany, "Language Laboratory Work for the Intermediate and Advanced Student"; Professor Kathryn Crecelius, "France's Backlash: Vive la difference?"; Professor David Dollenmayer, "An Urban Montage and Its Significance in Doblin's *Berlin Alexanderplatz*"; Professor Dyck, "Mathematics and Literature in the

German Enlightenment: A. G. Kästner" and "Der Gedichtschluss: Ansätze zu einer Theorie der Lyrik"; Professor James Harris, "Some Observations on 'Substantive Principles in Natural Generative Phonology,'" "Voiced Versus [+ Voice] in Spanish Obstruents," "Palatal \sim \emptyset Alternatives in Spanish," "Lo morfológico en una gramática generativa," and "Nonconcatenative morphology and Spanish plurals"; Professor Frederick Hodgson, "Indictment of Language and Reader Response"; Lecturer Irving, "Bringing Intercultural Communication into the English-as-a-Foreign-Language Classroom"; Professor Jones, "Critical Bibliography of Lenormand"; Senior Lecturer Kramsch, "Word-Watching: Learning Vocabulary Becomes a Hobby," "Total Immersion Weekend," and "Teaching Discussion Skills"; Professor Krystyna Pomorska, "On the Problem of Parallelism in Gogol's Prose," "The Overcoded World of A. Solzhenitsyn," "Observations on Tatjana's Letter," and "Chronotopos of V. Mayakovsky"; Professor Resnick, "El desafío de la palabra escrita: escritoras de la guerra civil española," and "The Cosmopolitan Esthetic of the Canary Island Surrealists"; Professor Jay Rosellini, "Wolf Biermann and Eurocommunism," "Politik and Subjektivität in der Lyrik der DDR," and "Die Aüsburgerung Wolf Biermanns aus der DDR"; Professor Edward Turk "The Birth of Children of Paradise" and "Marcel Carné's Greatest Films."

MARGERIE RESNICK

THE LITERATURE SECTION

After several years of effort and gradual change, the Literature Section now has in place and in practice, a reorganized curriculum in nearly final form. The key principles have been to narrow the number of offerings and to group them by tiers in ways that clarify the disciplinary frame of literary study both as it appears in the catalogue and as it is experienced in the classrooms. Most students taking our subjects are now in classes with other students who are at a similar level of preparation: beginning literature students are thus for the most part taking courses specifically designed for their needs, leaving the better-prepared students to work together on more sophisticated literary problems. The subjects in our introductory tier are few in number and all relatively broad-gauged intellectually, emphasizing the wide range of literary experience. Middle-tier subjects are somewhat more specialized, and represent the various subdivisions of literary study according to historical periods on the one hand, and genres and themes on the other, with a special subdivision for subjects in American literature. Finally, our seminar tier offers advanced students a chance to work in small groups (12 students or fewer) on subjects close to the teacher's own research interests: the general rubrics remain stable (e.g., Advanced Studies in Fiction) but content varies from year to year according to the rotation of faculty teaching these subjects. Students' response to these changes has been excellent, measurable both in steadily rising enrollments and in individual student comment to faculty and advisors. We offer a rich variety of over 40 different subjects and average better than 20 students per section.

Extensive searches this past year resulted in two appointments, one junior and one senior. We experienced a deep loss at the sudden death of our junior appointee, Sidonie Clauss. Her quality of mind and her promise as a teacher and scholar will be difficult to match. Our senior appointee, Professor Cynthia Wolff, is in the top rank of literary scholarship and will bring distinction to the humanities at MIT.

Members of the Section have been very active professionally this year. Instructor Susan Dickman is currently engaged in a major study of tragedy, for which the National Endowment of the Humanities has awarded her a grant this summer. An important part of this study concerns the medieval devotional tradition, about which she lectured this year at the University of California at Berkeley; she has been asked to address the Medieval Society at Harvard next year, the annual meeting of the Modern Language Association, and the Exeter Medieval Conference in England. She expects to submit a completed manuscript of her work to a university press by July 1980. Professor Peter Donaldson has published two major essays and has been elected fellow of the British Royal Historical Society. He has taught the popular Shakespeare course, chaired the committee making our four one-year appointments for next year, and coordinated the Western Traditions program. Professor A. R. Gurney's novel, *Entertaining Strangers*, went into paperback this year; his teleplay, *O Youth and Beauty*, was broadcast on Public Television in the Great Performances Series (October 31, 1979); and he has a new play optioned to open next October at the Greenwich Theatre, London.

Professor David Halperin's book on pastorals has been accepted for publication by Yale University Press. He has had an article on Epicurus and Solzhenitsyn accepted by *Critical Inquiry*; and his paper entitled "Mass Suicide and *Amor Mortis* in Lucan" was selected as among the best offered at the annual meeting of the Pacific Coast Philological Association and invited for submission to *Pacific Coast Philology*. Professor Louis Kampf edited a special issue of *Radical Teacher*, for which he also wrote an introduction and contributed an essay. Professor Alvin Kibel, on leave this year, has an essay on "Narrative into Film" in the spring 1980 issue of *Canto*, and another essay by him will appear shortly in the *Quarterly Review of Film Studies*. He has been appointed to the board of trustees of the University Film Studies Center and to the planning board of *Partisan Review*.

Professor Amy Lang lectured at Columbia University, Brown University, and the 1980 American Historical Association meeting, and published a review in the *Historical Journal of Western Massachusetts* (January 1980). Professor Travis Merritt, in addition to his teaching, leads the Course XXI office and served this year on the Committee on the Humanities, Arts, and Social Sciences Requirement.

Professor Ruth Perry's book, *Women, Letters, and the Novel*, has just been published by AMS Press, which has also reprinted George Ballard's *Memoirs of Several Ladies...* (1752) with her introduction and notes. She published two articles (on Sara Teasdale and *Tristram Shandy*) and has forthcoming in essay form two chapters of her biography of Mary Astell, currently in progress. She also served as consultant this year to a National Endowment for the Humanities (NEH) project on women's studies, and organized and presently chairs the Boston Eighteenth-Century Club.

Professor Robert Scanlan organized an extracurricular "Actor's Workshop" at MIT (summer 1979) and is writing a full-length play. Professor Barry Spacks, presently on leave, has forthcoming from the Johns Hopkins University Press a volume of *New and Selected Poems*, and has 16 new poems currently scheduled for publication in various journals.

Professor Stephen Tapscott, on an Old Dominion Fellowship this spring, has critical essays forthcoming in *Carolina Quarterly* and *Georgia Review* and poems in *Paris Review* and *American Poetry Review*. He has been awarded a poetry fellowship for this summer's Bread Loaf Writer's Conference.

Professor Tayler is on the supervising board of the English Institute and received an NEH Senior Scholar summer grant for 1980. She gave three public lectures this spring (at the University of Massachusetts at Amherst, New York University, and Brandeis University) and served on the Wellesley Exchange Committee.

Professor David Thorburn's *John Updike: 20th-Century Views* (Prentice Hall) came out this year. His most important service has been in chairing the Literature Section Curriculum Committee, both engineering and overseeing our important curricular innovations. He also has lectured widely on modern culture and the media, for example at this year's American Studies Convention and at the First Virginia Conference on the Family and Media.

Professor Wilburn Williams is presently revising his dissertation for publication. An essay of his, published in the *Massachusetts Review* (winter 1977), has recently been reprinted in *Chant of Saints* (University of Illinois Press, 1979), and he has a review article forthcoming in the *New York Times Book Review*. He lectured this year at the University of Virginia, the W.E.B. DuBois Institute of Harvard University, Wesleyan University, and Brown University.

Our morale as a Section is high partly because of the individual successes of our members and partly because we have worked together as a group this year with extraordinary pleasure and intellectual profit. Last fall we invited Professor Helen Vendler of Boston University to give a series of faculty seminars, in which she presented for discussion the major study she is just concluding on Keats. Before each meeting the members of the Section read the working draft of a section of her forthcoming book, then at the subsequent meeting raised questions and debated problems raised by Keats's texts and by Vendler's critical methods. She says that the experience was challenging and helpful to her; certainly it was to us. This started us off well, and the momentum was picked up by our two searches, in which all members of the Section participated fully at every stage except that of final recommendation, which was the responsibility of tenured

faculty alone. The result of such full Sectional participation was that we not only got to know one another much better intellectually but also enjoyed learning a great deal about the state of scholarship in the fields in which we were searching.

IRENE TAYLER

THE MUSIC SECTION

The sudden closing of Kresge Auditorium in September 1979 created problems for the performance organizations associated with the Music Section. That these problems did not interrupt our program is attributable to the quick and considerate actions of Dean Robert Holden, Dr. Louis Menand, Henry Leonard, and numerous people in the Physical Plant department. To all these, the Music Section wishes to give its most sincere thanks. Although a small number of scheduled programs were lost, most of the concerts went on as originally scheduled. Walker Memorial was efficiently transformed from a dining hall into a concert hall, where the MIT Symphony Orchestra, the Concert Band, the jazz bands, and the Brass Ensemble held their rehearsals and performances. For smaller ensembles and solo recitals, Room 10-250, the Sala de Puerto Rico, and the Hayden Gallery Sculpture Courtyard were put to use. Rental of halls outside the Institute was necessary only on occasions when the anticipated audience exceeded the capacity of these MIT facilities.

Outstanding among the 59 events thus made possible were a clarinet recital by Richard Stolzman; a performance by the Royal Dancers and Musicians from Bhutan; a performance by the Boston Musica Viva of Professor John Harbison's opera *Full Moon in March*, under the auspices of the Abramowitz Memorial Fund; an all-Ravel concert by the MIT Symphony Orchestra in Jordan Hall; and the MIT Choral Society's rendering of Johann Sebastian Bach's *St. Matthew Passion*.

The Music Section gave considerable attention this past year to curricular revision. The result is a variety of subjects for students with broad humanistic interests in music as well as for those wanting to learn music skills, history, theory, and performance practices. This revision seemed necessary; today our students ask for a greater variety of topics, for they enter the Institute with better preparation in the performance of music and with a broader musical perspective. Until recently, the study of music was comprised of instrumental and vocal training on the practical side, and of the theory and history of Western art music on the academic side. These subject areas, however, no longer cover the scope of musical events around us, nor do they satisfy the needs of students of music. Our shrinking world has acquainted us with many musical cultures, and our technology with new dimensions of sound. We are exposed to music of diverse styles and idioms -- folk, popular, light classical, and avant garde -- in much the way we are exposed to language in its conversational, popular, journalistic, and literary forms. The Music Section has retained an emphasis on Western art music in the new curriculum, but has attempted to recognize the need for study of this art in its social context and as a medium which lends itself to expression through modern technology.

Total enrollment was slightly above 1,200, a number which has remained stable over the last four years. There was an increase in the number of music concentrators; but as one moves into more advanced music subjects, enrollment figures fall off rapidly.

To report on the activities of individual faculty members, Professor Harbison enjoyed a number of distinctions. In addition to the performance of *Full Moon in March* mentioned above, his opera, *A Winter's Tale*, based on Shakespeare's play, was premiered by the Western Opera Theater, a division of the San Francisco Opera, in the War Memorial Auditorium of that city. He was honored with a commission for an orchestral work to be written for the Boston Symphony Orchestra centennial -- clear indication that he has become one of the prominent composers of his generation in America.

Professor David Epstein's book, *Beyond Orpheus: Studies in Musical Structure*, was published by the MIT Press. His article, "The Cessation of Audible Time: Musical Continuity and Conclusion," will appear in *The Study of Time* (Vol. IV, New York: Springer Verlag). He received the Composer's Award of the American Society of Composers and Publishers.

Professor John Buttrick was invited to participate in the International Chamber Music Seminar in Cornwall, England. He made concert tours of midwestern and western states, was soloist with the San Francisco Symphony, and recorded works of Brahms, Beethoven, and Schubert.

Professor Lowell Lindgren participated in the national meeting of the American Musicological Society (AMS), where he chaired the session on "Music and Drama, Seventeenth and Eighteenth Centuries." He read papers at the University of Hull, England, and the New England chapter meeting of the AMS at Brown University. Articles of his appeared in the *Musical Quarterly*, *Musical Times*, and the *Harvard Library Bulletin*.

Professor Erdely completed a monograph, "Ethnic Music in the United States: A Survey," to be published in the *Yearbook of the International Folk Music Council*. He is currently engaged in transcription and critical study of Serbo-Croatian epic songs of the Perry Collection, an assignment for Harvard University Press. He served as consultant to the National Endowment for the Arts, planning folk festivals in Detroit and New Jersey. The Erdely Duo gave recitals at the University of Connecticut and in a number of midwestern cities. The Duo also gave a concert for the World Council of Churches at MIT.

Professor Thompson won first prize in the National Black Music Colloquium and Competition sponsored by the National Music Council and the Kennedy Center. He gave recitals at San Diego State University, West Texas State University, and the Kennedy Center; and he appeared as soloist with the Salem Symphony Orchestra and the Boston Civic Symphony. Professor Thompson served on the panel of the National Endowment for the Arts for chamber music and solo artists, and he is vice president for education of Chamber Music America.

Professor Timothy Aarset wrote "An Introduction to Polyphonic Ensemble Improvisation" and "Venetian Ornamentation of Instrumental Ensemble Music circa 1600," both to be published in the *Journal of the American Recorder Society*. He recorded with the Boston Camerata and will be a member of the faculty of the Castle Hill Early Music and Dance Week, summer 1980.

Lecturer Mary Lewis's dissertation, *Antonio Gardano and His Publications of Sacred Music, 1538-1555*, has been accepted for publication by the MIT Press. She participated in the International Conference on Medieval and Renaissance Music at King's College, England, and received two grants for research trips to Europe.

Lecturer John Oliver received a Grammy nomination for best choral performance of the year for his recording of *American Choral Music* with the Tanglewood Festival Chorus on the Deutsche Gramophon label. The John Oliver Chorale has been recognized and partially funded by the National Endowment for the Arts as well as the Massachusetts Council for the Arts; the Chorale gave a series of performances of a wide variety of music, from Handel's *Messiah* to twentieth-century music, including Roger Sessions's *Three Choruses on Biblical Texts*.

Technical Instructor Claudia Von Canon's book *Moonclock*, published by Houghton Mifflin Company, Boston, will appear in a German translation published by Zsolnay in Vienna.

STEPHEN ERDELY

THE WRITING PROGRAM

In the academic year 1979-80, the Writing Program restructured and strengthened its subject offerings in the three primary areas of creative writing, essay writing, and scientific and technical writing. The Program's Curriculum Committee conducted an extensive review and evaluation of subject offerings. The upshot is a layered curriculum of introductory, intermediate, and advanced subjects in each area. Two new Humanities Distribution subjects -- Writing and Reading Poems, and Writing: Technology and Society -- have been added to the curriculum, bringing to six the total offered by the Writing Program. Other new subjects, such as Science Fiction, Longer Fiction, and Advanced Workshop in Scientific and Engineering Writing, expand students' opportunities to explore special areas.

Over and above its subject offerings the Writing Program teaches several cooperative writing programs, involving more than 1,000 graduate and undergraduate students. In addition to established programs in the School of Engineering, there are new programs in the Sloan School, the Department of Urban Studies and Planning, and the Technology and Policy Program. The Master of Science program in Science Communication, administered in Course XXV (Interdisciplinary Science) and staffed by Professors Rae Goodell and John Wilkes, admitted its first class of four graduate students in the fall of 1979; 10 more will enter the program in the fall of 1980. Since the program's goal is to train science communicators in the print and electronic media, a strong science background is required for admission. Once enrolled, students take subjects in science, as well as science communication, science policy, and related fields.

The Writing Program continues to offer a wide variety of more general Institute activities. Stanley Kunitz, Annie Dillard, and Toni Morrison were among the distinguished writers who came to speak and read to the Institute community. In addition, members of the Writing Program staff read from their own works in a series of Monday afternoon readings organized by Professor Ellen Bryant Voigt. Professor James Paradis organized an IAP seminar in technical writing; Professor Goodell and Professor Wilkes led an IAP project on "Covering the American Association for the Advancement of Science Meeting." Lecturer Harriet Ritvo directed a text-editing center.

Members of the Program have published extensively during the year. Professor Rothschild is coauthor of *Science and Technology in the New Socio-Economic Context*; her essay "Technology and the Image of the City" was published in *Proceedings of the Seminario Internacional Sobre O Desenvolvimento das Areas Metropolitanas*, and several of her reviews appeared in the *New York Review of Books* and the *London Review of Books*. Avon Books published Lecturer Fanny Howe's novel *The White Slave*. Professor Paradis and Professor Thomas Postlewait are coeditors of *Victorian Science and Victorian Values: Literary Perspectives*, to be published this year by the New York Academy of Sciences. The volume will include an essay by Professor Paradis on Darwin and one by Professor Postlewait on Shaw. Professor Elzbieta Chodakowska's *Comrades and Lovers: Rosa Luxemburg's Letters to Leo Jogiches* was published by the MIT Press; excerpts have appeared in several periodicals. Professor Voigt's poems have appeared in a variety of periodicals including the *New Yorker* and the *Georgia Review*. Professor Goodell's essays have appeared in the *Journal of Environmental Education*, the *New York Times*, and *Interdisciplinary Science Review*. Several of Lecturer Barbara Hartmann's poems have been published this year and an article by Lecturer Lee Warren appeared in the *Boston Globe*. Lecturer Harriet Ritvo has contributed to *Harvard Magazine*, the *Journal of the Society of Architectural Historians*, and *Humanities Report*.

The continuing projects of Program members also reflect the diversity of their interests and of the modes in which they write. Professor Voigt and Lecturer Robin Becker are both at work on new collections of poems; Professor Chodakowska is writing a biography of Rosa Luxemburg; Professor Paradis is editing the letters of Thomas Henry Huxley and preparing a textbook in technical communication; Professor Postlewait is analyzing Ibsen and the English drama; Professor Goodell is exploring the recombinant DNA controversy; Professor Wilkes has begun a study of alternative automobile engines; Lecturer Frank Conroy is about to complete a fictionalized description of the experience of an unusual family; Lecturer John Kirsch is at work on a sourcebook for teachers of engineering and writing.

Several members of the Program gave readings and talks. Professors Postlewait and Paradis participated in a special session on "The Language of Science and Its Influence in Victorian Culture" at the annual meeting of the Modern Language Association. Professor Paradis also delivered a paper on technical communication at the Institute of Physics. Professor Voigt was invited to read her poems at the University of Pittsburgh and Hampshire College, among other places. Professor Wilkes spoke about writing programs at Middlebury College.

Professor Rothschild has become an advisory editor of the *London Review of Books* and a member of UNESCO's Panel of Counselors in Long-Term Studies. Professor Paradis served as a consultant for the Brookhaven National Laboratory; Lecturer Warren was associate investigator for the Boston Harbor Management Study. Professor Wilkes was a member of the advisory panel for WBUR-FM's series on science and technology. Active in many professional organizations in the field of science writing, Professor Goodell is a member of the board of directors of the Council for the Advancement of Science Writing and she serves on the editorial advisory committees of the Forum for the Advancement of Students in Science and Technology and of the Science and Children's Television project of Action for Children's Television.

The Writing Program Advisory Committee, composed of Professor Chodakowska, Professor Anthony French of the Department of Physics, Jay Lucker, Director of the Libraries, and Professor Resnick, Head of the Foreign Languages and Literatures Section, continued to help with administrative matters. Because Professor Rothschild, Director of the Writing Program, was on leave during the spring semester, Professor Cartwright, Acting Head of the Humanities Department, served for that period as Acting Director of the Program, and Lecturer Ritvo was appointed Assistant Director.

RICHARD L. CARTWRIGHT

Department of Linguistics and Philosophy

This report will focus on three aspects of the Department's activities during the academic year, namely teaching, research, and service.

With respect to teaching, two programs deserve special mention. First, in the area of undergraduate education the Department continued its effort to develop a unified undergraduate program in Language and Mind. Among the first steps taken toward this goal has been the development of a comprehensive curriculum dealing with topics ranging from the philosophy of language to the acquisition of phonology. Faculty from the Department of Psychology as well as from the Division for Study and Research in Education (DSRE) are participating in this effort, along with members of the Department. Funded by a grant from the National Endowment for the Humanities, this effort is intended to produce a unified curriculum as well as teaching materials and textbooks.

The success of the Independent Activities Period (IAP) lecture series on Intelligence (see below) sponsored by the Department during January 1980 led to the introduction of a new undergraduate subject to be offered in the Department by Professor Daniel Osherson of the Department of Psychology and the DSRE. This course is entitled Introduction to Cognitive Science and will deal with some major issues in cognitive science, including induction and inductive logics as psychological theories, concepts and conceptual composition; the problem of natural concepts; and images and percepts.

At the graduate level Professor James Higginbotham of Columbia University has been invited for the academic year 1980-81 as a visiting professor in philosophy. He will replace Professor Sylvain Bromberger during the latter's sabbatical year away. Professor Higginbotham will introduce a new subject which attempts to integrate the linguistic and philosophical interest in natural language semantics. Until recently no such subject has been available. This innovation promises to be extremely fruitful, not only improving the graduate offerings in linguistics but also taking advantage of the strong overlap of interests between linguistics and philosophy.

In addition to the introduction of new subjects, the Department sponsored several lecture series during the past academic year. One, already mentioned, took place during IAP and was presented by the faculty interested in developing a Language and Mind curriculum. The general topic of the lectures was Intelligence and the participants and their topics included "Brute Intelligence: Apes and Bees," Professor Osherson, DSRE and Department of Psychology; "Perceptual Intelligence: Thinking without Words," Professor Molly Potter, Department of Psychology; and "Linguistic Intelligence: What Adult Speakers Know," Professor Noam Chomsky, Department of Linguistics and Philosophy.

A second IAP lecture series, sponsored by the Philosophy faculty, was entitled Philosophical Problems. Speakers and topics included "Problems about Knowledge," Professor Judith Thomson; "Film Aesthetics," Professor Irving Singer; "The Possibility of Time Travel," Professor Paul Horwich; and "Are We Computers?" by Professor Ned Block.

Finally, several colloquia were held throughout the year and guest speakers included Professors Terence Langendoen, City University of New York; R. M. W. Dixon, Australian National University; Jean-Roger Vergnaud, University of Massachusetts at Amherst; Mark Blatin, New York

University; Derek Parfit, Oxford and Princeton; Gareth Matthews, University of Massachusetts at Amherst; Rogers Albritton, University of California at Los Angeles; and Margaret Wilson, Princeton.

RESEARCH

Linguistics

Supported in part by a grant from the National Science Foundation, Professor Kenneth Hale and his colleague Dr. Mary Laughren of the Department of Education, Government of the Northern Territory of Australia, continued research on a lexicography of Aboriginal Australian languages. Professor Hale also continued research on other topics, including the use of linguistics in a science curriculum in primary and secondary education, with special attention to "local language" communities.

Professor Paul Kiparsky has spent much of his time continuing his research into cyclic and metrical phonology and has a book in preparation on these topics. In addition, he has worked in Germanic syntax and jointly offered a subject on the topic this past semester with Professor Wayne O'Neil. His book, *Panini as a Variationist*, has been published jointly by Poona University Press and by the MIT Press.

Professor Joan Bresnan has been working intensively in the theory of lexical rules and representations and has published several papers in this area dealing with passivization, instrumentalization, and control and complementation in English. In addition, she has continued her collaboration with Dr. Ronald Kaplan of XEROX's Palo Alto Research Center and Dr. Marilyn Ford of the Center for Cognitive Science at MIT on problems relating to lexico-syntactic interactions in parsing models.

Professor Chomsky has extended his work in the theory of government and binding as well as his work dealing with problems in cognitive psychology and the theory of knowledge. A major thrust of his research has been in exploring the notion of Universal Grammar as a set of interacting subsystems. During the past year several articles on these subjects have appeared as well as his latest book *Rules and Representations*, Columbia University Press, New York, 1980.

Professor Morris Halle has worked extensively in the theory of metrical structure. He is presently preparing a monograph on metrical phonology, coauthored with Dr. Vergnaud of the University of Massachusetts at Amherst. He is also continuing his research with Dr. Kiparsky into Indo-European accentuation.

Professor James Harris continues his work in Spanish linguistics, with special emphasis on morphology and prosody. He has delivered several invited papers on these topics, both in the United States and abroad. He also is working in the area of phonetic theory and is collaborating in this regard with Professor Halle and Professor Kenneth Stevens of the Department of Electrical Engineering and Computer Science.

Professor Samuel Jay Keyser is working in the theory of literature, metrical structure in phonological theory, and in the history and structure of the English language. He is presently preparing, with Dr. Alan Prince of the University of Massachusetts at Amherst, a monograph dealing with the poetry of Wallace Stevens. With G. N. Clements, he has just completed a metrical study of Klamath, an American Indian language, and is presently working on a monograph with Professor O'Neil dealing with the history of English from a metrical point of view.

Professor O'Neil, who has just become a full-time member of the linguistics faculty of the Department of Linguistics and Philosophy, has spent the past year working on the syntax of Old Norse (skaldic) verse. His published work includes contributions in historical Germanic morphology and in English orthography.

Professor John Robert Ross continues his long-standing interest in the structure of poetic form and the theory of poetry. He has been working in the area of the structure of conversation and the role of gesture in conversation as well as in the relationship of language and art. He is

presently working on the final draft of a book on theoretical syntax to be published in the Ablex series, *Language and Being*; the work is tentatively titled "Infinite Syntax."

Philosophy

In the area of philosophy of mind and psychology, Professor Block has published several articles including one on innateness and another on absent qualia. He is continuing research on forthcoming articles on functionalism and psychologism and behaviorism.

Professor George Boolos is continuing research on provability interpretations of modal logic, and is planning to edit, with Professor Warren Goldfarb of Harvard, a volume of English translations of the works of Kurt Gödel, to be published under the auspices of the Association for Symbolic Logic.

In the field of political philosophy, Professor Joshua Cohen is working on two general projects. The first is a comprehensive treatment of Marx's theory of society. The second, with Professor Charles Sabel from the Program in Science, Technology, and Society, is an account of social transformation and incorporates ideas in social theory and the philosophy of social science, together with historical investigation. A portion of this project will be presented at the American Political Science Association Convention in September.

Professor Judith DeCew has continued research in three areas: conditional obligation within tensed deontic logic; ultimate foundations of natural law theory and a comparison of such a view with positivism and realism; and the relationship between legal and moral treatment of rights and responsibility.

In addition to preparing an essay on Wittgenstein's philosophy of mathematics, Professor Horwich has been revising the manuscript of his book on "Probability and Evidence," which has been accepted for publication by Cambridge University Press.

During his first year with the department, Professor Thomas Kuhn continued his work on the relationship between philosophy of language and of science, and published several articles on the history and philosophy of science.

Professor Singer continued the writing of a sequel to his book *The Nature of Love: Plato to Luther*.

Professor Judith Thomson continued work on her book on the concept of a right.

In addition to their regular duties, several members of the Department were involved in service to the Institute. In particular, three people devoted an unusually large amount of their time to Institute duties.

Professor Richard Cartwright served as Acting Head of the Department of Humanities, Acting Director of the Writing Program of that department during the spring term, and as Associate Chairman of the Faculty. Professor Bromberger, in addition to being Chairman of the Philosophy Program, was an active member of several Institute committees, including the Committee on Graduate School Policy subcommittee on graduate subjects (Chairman); Humanities, Arts and Social Sciences Committee; and the MIT Press Editorial Board. Professor Halle served on the Faculty Advisory Committee on the Presidency and the Wiesner Retirement Committee.

Miscellaneous Notes

Professor DeCew was one of six recipients of a Liberal Arts Fellowship in Law from Harvard Law School and will spend academic year 1980-81 at that institution.

While on sabbatical leave, Professor Boolos spent the spring term in Oxford, England and gave lectures on mathematical logic at universities in Siena and Padova, Italy as well as at Oxford and Cambridge universities.

Professor Harris was awarded an American Council of Learned Societies travel grant to attend the Congr es International de Linguistica i Filologia Rom niques, in Palma de Mallorca, Spain in April 1980.

Professor Bresnan was a member of the advisory panel of the Division of Information on Science and Technology of the National Science Foundation.

In January, Professor O'Neil traveled to Peking and ran a workshop in linguistic theory and its application to language teaching. The workshop was attended by 50 Chinese teachers of English and was sponsored by the Peking Normal University and the Chinese Bureau of Foreign Experts.

As usual, the Department was host to several visiting scholars from this country and abroad. They included: Drs. Adriana Belletti, University of Pisa; Hugh Bredin, Queen's University at Belfast; Guglielmo Cinque, University of Padova; Brian Ellis, LaTrobe University; Julia Horvath, University of California at Los Angeles; Alexa McCary, Georgetown University; Eric Reuland, University of Groningen; Luigi Rizzi, University of Pisa; Jerzy Rubach, University of Warsaw; Takeo Saito, Tokyo University of Education; Hendrik van Riemsdijk, University of Amsterdam; and Eric Wehrli, McGill University.

During the spring term, Michael Williams, Yale University, was a visiting professor of philosophy and offered a graduate seminar on Hume.

SAMUEL JAY KEYSER

Department of Political Science

Introduction

The most notable events of the past year involved the Department's graduate program. First, in consequence of a variety of actions by the Institute administration, described below, the Department's severe problem of providing adequate financial support for graduate students has been significantly (if only partially) alleviated. Second, the Department sponsored a conference and engaged in continuing discussion of how best, in a period of contracting academic job opportunities, to provide political science graduate students with non-academic career options. The undergraduate internship program reached a new peak of success, stimulated in part by the Presidential primary during the spring; but continuation of this program at its current scale beyond 1980-81 is threatened by the exhaustion of its current, and nonrenewable, base of foundation support.

Graduate Program

Two years ago the annual report noted that over the previous four years graduate student financial aid had declined by 11 percent, even as tuition and student living costs had increased by 40 percent. The effects were being felt not merely in the form of student hardship, but also in the Department's ability to attract graduate students. Only two of the top 10 students admitted that spring had chosen to accept the Department's offers.

Great progress has been made during the interim. The key decisions were made during 1978-79 but have been fully implemented only this past year. General funds available for student aid have increased by 133 percent, and funds allocated to the Department under the Federally supported work-study program have increased by 67 percent. Additionally, post-generals students have become eligible for either of two new arrangements that reduce their effective tuition costs. If they are non-resident, they can remain in good standing by paying a fee equivalent to

15 percent of tuition. If they are resident but employed neither as research assistants nor teaching assistants, they are eligible for a new category of 75 percent tuition scholarships. Students in both categories remain eligible for student loans, and those in the latter category may, if they are eligible on all other grounds, participate in the work-study program. These means of reducing the tuition burden on advanced graduate students are particularly important to the Department of Political Science, because they bring MIT more closely into line with its leading social science competitors, and because relatively few political science graduate students are able to obtain employment as research assistants.

In consequence of these developments, student aid adjusted for inflation has again approached the level of the early 1970s and the Department has managed to attract about 40 percent of the candidates for admission that it has ranked most highly over the past two years. (By 1979-80, tuition and living costs were 71 percent higher than 1973-74, while graduate student financial support was 56 percent higher.) MIT remains very significantly handicapped, unfortunately, in competing for the best political science graduate candidates by its inability to offer any multi-year fellowships. And the difficulty of financing graduate education in political science remains severe from the graduate student standpoint. The progress of the past two years has been most notable, however, particularly in that it has occurred during a period of extreme fiscal stringency at MIT and throughout the nation.

The faculty devoted considerable attention in 1979-80 to the question of how best to adapt to the changing market for Political Science Ph.D.s. Traditionally, the nation's leading social science departments have focused at the graduate level on training for academic careers. The MIT Political Science Department has displayed this orientation less than most, having always had a strong orientation toward problem solving as well as the advancement of abstract knowledge. Even so, three-fifths of those who have ever received MIT doctorates in Political Science are currently employed by colleges and universities.

The employment market is changing dramatically, however. Fiscal pressures are leading many colleges and universities already to increase their student-faculty ratios. Faculty attrition is expected to decline in the years ahead because of the recent increase in the legal minimum mandatory retirement age from 65 to 70. And the nation's 18 to 24 year-old cohort will decline by roughly one-quarter over the next two decades. There is substantial controversy about whether and how much actual enrollments will decline during this period, but it seems likely that the number of entry-level academic opportunities will substantially decline and that academic salaries may become even less competitive with those in other high-skill occupations than during the past several decades. These trends are already quite visible.

Meanwhile, opportunities in government, policy research, consulting, the management of non-profit institutions, and even the private corporate world are continuing to expand. The Department's recent job placement experience and the testimony of its non-academic alumni both suggest there is little danger that these markets will become saturated with well-trained political scientists who are oriented toward public problem solving and policy analysis.

The Department sponsored a conference in February addressed to the question: how can the faculty, without forcing students to choose prematurely between academic and non-academic career options, best assist them to become highly marketable for non-academic positions? The conferees included MIT faculty, graduate students, and placement personnel, together with 15 invited outside panelists. All of the latter were political science Ph.D.s (13 of whom obtained their degrees from this Department) who are currently pursuing non-academic careers.

The conference was structured around three successive panels, focused respectively on careers in public management, policy research, and private corporate administration. Each panel included five of the invited outside participants and was moderated by a member of the faculty. The panelists exemplified in their diversity the wide range of non-academic careers to which students might aspire. Nonetheless, a number of themes ran consistently through the discussions. Some of these involved the importance of particular skills -- in communications, quantitative techniques, and economics, for example. Others involved socialization -- for example, to the simple idea that non-academic careers are often as satisfying and worthy of respect as academic. Numerous panelists stressed the value of internships in non-academic work environments during graduate school, and indicated they would themselves be more than pleased to assist in placement. There was general agreement that the Department should take advantage of its considerable network of non-academic alumni in developing an effective graduate intern program.

Subsequent to the conference, these matters were further discussed with the Department's Visiting Committee in April, and plans for implementing a number of specific action items were developed by an ad hoc faculty-student committee (chaired by Professor Harvey Sapolsky).

The Graduate Program Committee, chaired by Professor Hayward Alker, carried out a thorough review of graduate program requirements during 1979-80, and brought forth a report including 17 action recommendations for consideration by the full faculty in May. With minor amendments the faculty voted to adopt the entire report.

The Graduate and Undergraduate Program committees together supervised the Department's first multi-year curriculum planning exercise as well during the year. Subdividing into five field planning groups, the faculty established teaching priorities, identified important gaps likely to be created as a result of anticipated faculty leaves, and developed recommendations for filling the gaps by redeploying the time of faculty already scheduled to be in residence. The faculty carried out this exercise in an extremely effective spirit of cooperation, with positive results that should become apparent to Political Science graduate students, undergraduate majors, and concentrators in the years ahead. In accord with the Department's new policy on faculty leaves, adopted in May 1979, the curriculum plan developed in 1979-80 will henceforth be updated annually.

Undergraduate Program

The Department has benefitted over the past three years from a Sloan Foundation grant to develop undergraduate activities in the field of public policy. Most significantly, the Sloan grant has enabled the Department to employ a full-time administrator of undergraduate internship activities and to expand its financing of undergraduate summer internships. During 1979-80 the Department's intern program accounted for 108 (unpaid) placements during the academic year and 22 (paid) during the summer. As the summer program has grown, the base of Sloan funding has been supplemented by support for stipends from the Departments of Political Science and Urban Studies and Planning, the Program in Science, Technology, and Society, and the Undergraduate Research Opportunities Program (UROP). The academic year program is built primarily around three subjects, one of which is a joint offering with the Department of Urban Studies and Planning. Both the academic year and summer components of the program include very substantial faculty-student-staff interaction throughout the internship period to ensure that the students reflect, do collateral reading, and write about their experiences. It likewise requires considerable interaction with workplace supervisors to secure a continuing flow of placement opportunities and to maximize the likelihood that interns will receive stimulating assignments.

As noted above, considerable agreement has developed over the past year that the Department should now move on to develop an internship program for graduate students, particularly those who are seriously considering non-academic careers. But the Sloan grant will run out during 1980-81, jeopardizing the Department's capacity to operate even the undergraduate internship program at anything approaching its current scale and quality. A major effort will therefore be launched during 1980-81, in cooperation with the Department of Urban Studies and Planning, to raise follow-on funding for the continuation and expansion of internship activities.

Relationships with the Program in Science, Technology, and Society (STS)

The Department has followed the continuing evolution of the STS Program with increasing interest, recognizing that it offers an opportunity of great value to expand the Institute's capabilities in fields immediately adjacent to several that have long been of central interest to the Political Science faculty. During 1979-80 notable progress was made toward formalizing collaborative arrangements between the Department and the Program. In 1980-81 the Program will fund several fellowships for graduate students and stipends for undergraduate summer interns whose interests lie at the interface of Departmental and Program concerns. Three members of the Program faculty also will be offering courses in the Department. Discussions of a possible joint graduate degree program are expected to continue.

FACULTY

Public Service and Community Activities

Professor Lincoln Bloomfield was on leave in 1979-80, serving as the senior staff member of the National Security Council in charge of global issues. Professor George Rathjens returned in February from a two-year assignment as senior deputy to the President's Special Representative for Nuclear Non-Proliferation. Professor Ted Greenwood returned in the summer of 1979 from two years as a senior staff member in the Office of Science and Technology Policy (OSTP), Executive Office of the President. He and Professor Eugene Skolnikoff both served as part-time consultants to OSTP during 1979-80, as did Professor William Griffith to the National Security Council. Professor William Kaufmann served as a consultant to both the Secretary of Defense and the Secretary of Energy, and was honored by the former with a Department of Defense Distinguished Public Service Medal.

Professor Lucian Pye was a director of the Council on Foreign Relations, the Asia Foundation, and the World Affairs Council of Boston. He also served as vice chairman of the National Committee on US-China Relations. Professor Robert Rotberg was a trustee of the World Peace Foundation, moderator of the Citizens Committee for Lexington Schools, and president of the Oberlin College Alumni Association. Senior lecturer Edwin Diamond chaired the National Science Foundation Committee on New Technologies and Television. Professor Sapolsky served as a member and subcommittee chairman of the National Academy of Sciences Committee on the Health Effects of Ionizing Radiation. He also did consulting for two other NAS committees dealing with public health issues and for the Veterans Administration. Senior lecturer Louis Menand continued as vice chairman of the Academic Freedom Committee of the American Civil Liberties Union.

Professor Michael Lipsky was a member of the Roxbury Crossing Welfare Advisory Board and two subcommittees of the Massachusetts State Welfare Advisory Board. Professor Greenwood chaired a task force on Indochinese Resettlement which assisted Vietnamese refugees seeking to locate in the Greater Boston area. Professor Stephen Meyer provided analytic services to both the Boston Environmental Health Improvement Program and the Massachusetts Law Reform Institute.

Professor Ithiel Pool continued as chairman of the Committee of Concern about Institutional Review Board Practices. This ad hoc group of scholars from throughout the United States played a leading role during 1979-80 in the effort to prevent the US Department of Health, Education and Welfare from issuing a proposed set of regulations that could severely impair the freedom of social science researchers. The substance of this issue was reviewed in the Department's report for 1978-79. Attention is also directed to Professor Pool's article, "The New Censorship of Social Research," which appeared in *The Public Interest* (Spring 1980). The potential significance of this matter for the future of American social science can scarcely be overstated.

Professional Activities

Professor Myron Weiner became chairman during 1979-80 of the Committee on South Asia of the Social Science Research Council and the American Council of Learned Societies. He also was elected president of the New England Association for Asian Studies. Professor Nazli Choucri was elected to the governing council of the American Political Science Association and served as US representative on the International Social Science Documentation Committee. Professor Alker chaired the Committee on Mathematical Approaches to Politics of the International Political Science Association and continued as an active member of the Committee on Undergraduate Education of the American Political Science Association. Professor Emma Jackson served as a member of the executive council of the National Conference of Black Political Scientists and of the Gabriel Almond Dissertation Award Committee of the American Political Science Association.

Professor Lipsky took 80 percent leave during the year to serve as director of Policy Studies for the Legal Services Institute (LSI). LSI is a practice-training center for Harvard and Northeastern law students and MIT students of public policy. It is funded by a combination of grants from the US Legal Services Corporation, ACTION, and the Harvard Law School. Professor Walter Dean Burnham spent the year in Palo Alto, California as a fellow of the Center for Advanced

Studies in the Behavioral Sciences. Professor Suzanne Berger spent the year in Paris as a Guggenheim Fellow.

Professor Pye chaired the nominating committee of the committee of the International Association of Political Psychology and served as vice chairman of the advisory committee to the University Service Centre, Hong Kong. Professor Skolnikoff continued as a member of the board of trustees of the German Marshall Fund of the United States. Professor Willard Johnson devoted the fall semester to work on a book about African-Arab relations, and served as a member of the boards of the Association of Concerned African Scholars and the African Heritage Studies Association. Professor Pool was a member of the Committee on Mass Communications of the Social Science Research Council.

Numerous members of the faculty were active in editorial roles. Professor Martha Weinberg continued as coeditor of the MIT Press Series on American Politics and Public Policy, and Professor Berger continued as coeditor of the Cambridge University Press Series on Modern Political Economics. Instructor Thomas Ferguson became editor of the Sage Series in Political Economy. And various faculty members served on the editorial boards of the following journals: *Administration and Society* (Professor Lipsky), *Political Psychology* (Professor Lloyd Etheredge), *Journal of Health Politics, Policy, and Law* (Professor Deborah Stone), and *Magazine Reports* (Mr. Diamond).

MIT Activities

Professor Donald Blackmer continued as director of the Program in Science, Technology, and Society and as Associate Dean of the School of Humanities and Social Science. Professor Skolnikoff remained director of the Center for International Studies. Professor Alan Altshuler served as co-director (with Professor Daniel Roos) of a multinational study of "The Future of the Automobile," as vice chairman of the faculty executive committee of the Joint Center for Urban Studies (chairman beginning May 1980), as a member of the executive committee of the Center for Transportation Studies, and as a member of the Upward Bound Steering Committee.

Professor Choucri was associate director of the Technology Adaptation Program and chairperson of its Policy Committee. She and Professor Pool continued to direct research projects in Egypt within the framework of this Program. Professor Choucri also served as a member of the advisory committees of the Aga Khan Program for Islamic Architecture, the Technology and Development Master's Program (in preparation), and the Statistical Computing Program. Professor Pool continued to direct the Research Program in Communications Policy. Professor Sapolsky remained deputy director of the University Health Policy Consortium, chairman of the Standing Committee on the Lincoln Laboratory, and a member of both the Whitaker College Council and the Medical Department Administrative Board.

Dr. Menand continued to serve half-time as Special Assistant to the Provost, and in that capacity to serve on numerous Institute committees. Professors Greenwood and Rathjens served on the steering committee of the Arms Control and Defense Program, while Professors Greenwood and Weinberg were members of the steering committee of the Technology and Policy Program. Professor Weinberg was also a member of the Committee on Student Affairs. Professor Weiner served on the MIT Press Management Board. He also co-chaired the Harvard-MIT Joint Seminar on Political Development and the Boston University-MIT Boston Area Seminar on South Asia. Professor Kaufmann was a member of the Institute's Foreign Scholarship Committee. Mr. Diamond served on the Provost's Student Press Committee.

PUBLICATIONS

Books and monographs published by members of the Political Science faculty during 1979-80 included the following:

Hayward Alker (with Roger Hurwitz), *Resolving Prisoners' Dilemmas*, American Political Science Association.

Alan Altshuler (editor and contributor), *Current Issues in Transportation Policy*, Lexington Books.

Suzanne Berger (with Michael Piore), *Dualism and Discontinuity in Industrial Societies*, Cambridge University Press.

Nazli Choucri, *International Energy Policy: Petroleum Prices, Power, and Payments*, MIT Press.

Edwin Diamond (with Bruce Mazlish), *Jimmy Carter: a Character Portrait*, MIT Press.

William Griffith, *The West European Left*, Lexington Books.

Michael Lipsky, *Street-Level Bureaucracy: Dilemmas of the Individual in Public Service*, Russell Sage.

Donald Morrison, *Black Africa: a Comparative Handbook*, Irvington Press.

Robert Rotberg, *Suffer the Future: Policy Choices in South Africa*, Harvard University Press; and (editor and contributor), *Conflict and Compromise in South Africa*, Lexington Books.

Harvey Sapolsky (with Drew Altman and Richard Greene), *Health Planning and Regulation*, Health Administration Press; and (coeditor and contributor), *Federal Health Care Programs*, Lexington Books.

Among the more significant articles published by members of the Department during the past year were:

Alan Altshuler (with C. Kenneth Orski and Daniel Roos), "The Future of the Automobile," *Transatlantic Perspectives*.

Suzanne Berger, "The Uses of the Traditional Sector: Why Declining Classes Survive," in F. Bechofer and B. Elliott, eds., *The Petty Bourgeoisie*, Macmillan.

Walter Dean Burnham, "American Politics in the 1980s," *Dissent*; and "1980 as an Historical Moment," *Washington Quarterly*.

Nazli Choucri, "International Political Economy: A Theoretical Perspective on System Change," in Ole Holsti, et. al., eds., *Change in the International System*, Westview Press; and "The International Petroleum Exchange Model," *Futures*.

William Kaufmann, "Defense Policy," in Joseph A. Pechman, ed., *Setting National Priorities in the 1980s*, Brookings.

Michael Lipsky, "The Welfare State as a Workplace," *Working Papers*.

Stephen Meyer, "Verification and the ICBM Shell Game," *International Security*; and "Politics Among Data," *Naval War College Review*.

Ithiel Pook, "The US Faces WARC," *Journal of Communication*; and (with Richard Solomon), "Transborder Data Flows: Requirements for International Cooperation," *Telecommunications Policy*.

Harvey Sapolsky, "Political Obstacles to the Control of Cigarette Smoking in the United States," *Journal of Health Politics, Policy, and Law*.

Deborah Stone, "Comparing National Health Care Costs: The German Experience," *Transatlantic Perspectives*.

Martha Weinberg, "Boston's Kevin White: A Mayor Who Survives," *Political Science Quarterly*.

Myron Weiner, "Social Science Research and Public Policy," *Economic and Political Weekly*; and "Seeking Ethnic Equality," in John Montgomery, et. al., eds., *Patterns of Policy*, Transaction Books.

Department of Political Science

PERSONNEL

One of the founders of the Department, Daniel Lerner, Ford Professor of Sociology and International Communications, died of cancer at the age of 62 this spring. He had been on extended medical leave for the past three years. Professor Lerner came to MIT from Stanford University and the Hoover Institutions in 1953. He authored more than 20 books during his career, including at least one genuine classic, *The Passing of Traditional Society* (1958). In addition, he directed the MIT Hayden Colloquium on Scientific Method and Concept from 1957 to 1966, which produced four important books of articles. He also founded and led, during the years 1954-65, the Institut d'Etudes Europeennes in Paris. This work produced two major books, *Euratlantica: Changing Perspectives of European Elites* (coauthored with Morton Gorden), and *France Defeats EDC* (coedited with Raymond Aron). Professor Lerner was a major figure in the history of this Department and of contemporary social science. He was also a warm and delightful colleague who will be sorely missed.

Deborah Stone was promoted to associate professor during 1979-80, and four new faculty members were appointed. One of these, Professor Peter Smith, a specialist in Latin American Politics, will hold a joint appointment in the Departments of Humanities and Political Science. He also will serve as Head of the Humanities Department. The other three new appointees, all assistant professors, are: Russell Neuman, a political sociologist specializing in communications policy, who has been teaching at Yale; Brian Smith, a Latin Americanist who received his doctorate from Yale in 1979; and Richard Samuels, a recent product of this Department, whose specialties are Japanese and comparative urban politics. The Department continued for the second year in a row to search without success for a specialist in the field of science, technology, and politics. Given the very high level of student interest in this field and the shift to other activities of several faculty who formerly provided leadership in it (most notably, Professors Skolnikoff and Sapolsky), filling this position remains an extremely high priority and the search will continue next year.

ALAN ALTSHULER

Department of Psychology

Growth, both actual and prospective, has been the most striking outcome of the Department's activities. Three years ago, we expressed concern about the constraints on continued development -- a concern which was echoed in more recent reports. Now in 1980, we think we are on the verge of a period of controlled expansion. New areas of research have opened up and funding has either been found or is imminent. Laboratory space has fortunately been increased through room use in other buildings, and will further increase when the Whitaker Building is completed. The second of the two largest (and among the best qualified) graduate student classes in recent years has been accepted. All these developments attest to the Department's continued health and prosperity. The following reviews expand on the current developments.

RESEARCH

As in previous years, research support continued to increase. In addition to the traditional research interests of the Department, at least three new directions are developing: The first of these has been named "Natural Computation" by Professor Whitman Richards, who shepherds its destiny. A group of mathematically talented psychologists, physiologists, engineers, and others are engaged in an intense effort to formulate the computational structure required to solve problems of perception and other functions of the nervous system. Professor David Marr has provided leadership in this endeavor and has been ably seconded by colleagues in laboratories here at MIT and abroad. A key element in this program is the realization that computational

solutions to these problems transcend the particular hardware which carries out the computation. Consequently, the problem-solving apparatus may be realized equally well by aggregates of neurons as by collections of transistors. Tangible recognition of the power of this approach has come in the form of increased funding from governmental agencies.

Secondly, the new Center for Cognitive Science has provided an excellent vehicle for expanding the work of our cognitive psychologists. They have found enhanced intellectual stimulation from the close association with linguists, philosophers, and colleagues in the Artificial Intelligence Laboratory, and are anticipating continued collaboration in the future. New research space has been provided within the Center area and new funding, not reflected in the Departmental budget, has allowed its members to bring in additional postdoctoral and visiting scientists. We look forward to further expansion of this Center.

Finally, our brain scientists are anticipating two new developments. Completion of the top floor of the Whitaker Building will give them new and improved research and teaching space, and, juxtaposition with the adjacent laboratories of Professor Richard Wurtman will further the already active collaboration with his group of neuroendocrinologists. We are, however, concerned that the physical separation of parts of the Department may lead to lessened communication among them. In addition, a subcommittee of the Whitaker College Advisory Committee is considering nominees for new positions in the neurosciences within the Whitaker College itself. Such appointments would considerably strengthen the existing program in the brain sciences.

TEACHING

Although the Department is most strongly committed to its research efforts, teaching still occupies a vital position among our activities. New teaching ventures, in the form of interdepartmental collaboration, have included a joint course given by Psychology Professor Merrill Garrett and Linguistics Professor John Ross on Serial and Temporal Factors in Language Processing (9.590J); The Psychology of Reasoning (9.631J), taught by Associate Professor Dan Osherson, who holds a joint appointment in our Department and in the Division for Study and Research in Education (DSRE); and a Graduate Seminar in Sensation and Perception (9.351), taught by Professor Richard Held and a graduate assistant, Jeremy Wolfe. All in all, some 600 students were taught by our teaching faculty. Psychology maintained a fairly stable position among the undergraduates' fields of interest: 87 seniors completed their Psychology concentration, while 44 undergraduates are still registered as "in progress." The Undergraduate Research Opportunities Program (UROP) on the other hand, rose from four students in the fall to 14 this past spring, the highest number we have had thus far.

The format and scope of our undergraduate instruction will remain largely the same, but several course changes are already under way. For example, a new Human Development course (9.90J) will be offered by Professor Osherson in the spring of 1981, replacing the old Developmental Psychology course (9.89) taught so ably for the past 10 years by Professor Susan Carey; and Professor Stephen Chorover is planning a new course on Affect (9.68).

The graduate training program will undergo a thorough revamping during the next year (or two), beginning with the introduction of two Neuroscience subjects (9.014J and 9.015J), the first one starting in the spring of 1981. This new sequence is designed as a graduate-level introduction to the broad range of contemporary topics in the brain sciences. At the same time, we expect the organization of a basic graduate subject or sequence in the Cognitive Sciences. Both these courses will serve as introductions to the common core of knowledge required for study and research in these fields.

As usual, our well-known colloquium series continues to be an important part of our training program as well as an asset to the local community of behavioral and brain scientists. During the past academic year we presented 35 colloquia and 13 special seminars, with 12 of the speakers coming from abroad (from Norway, Switzerland, Sweden, Australia, Scotland, Israel, Denmark, Germany, and China).

Graduate Program

The graduate program, long held back from expansion for reasons of economics and space, received a vigorous infusion of new talent last fall. In fact, this past year we were able to accept 11 new graduate students because five of them came with fellowships of their own: three from the National Science Foundation (NSF), one from Hughes Aircraft, and one from the Natural Sciences and Engineering Research Council of Canada, a very favorable statistic considering that a total of 30 NSFs in psychology were awarded across the country in 1979-80. The largest first-year group in a decade, this new class will be followed by a 10-member class this coming fall made possible again because three have NSF fellowships. In the meantime, having awarded the Ph.D. to three students during the 1979-80 period, we expect to grant four more during the summer of 1980. By the time classes meet in the fall, our graduate student body, now 32 strong, should number 38-40, and 70 Ph.D.s will by then have graduated from our Department. The latest candidates have been accepting positions as far away as UCLA and the Stanford Research Institute, and as near as Brown University and the National Institutes of Health in Bethesda, Maryland.

Postdoctoral Researchers and Visitors

The Department continues to attract many more postdoctoral applicants than it can accept. While most of the 15 currently aboard hail from this country, two of them came from as far away as Rio de Janeiro and Melbourne.

However, training is not only sought by young professionals. Senior professional colleagues, too, come to this Department to familiarize themselves with directions of new research, with new techniques and/or with the general ambience. Among these many visitors, some came to stay for a number of months: Professor Arien Mack, New School for Social Research, NY; Professor Max Cynader, from Dalhousie, Nova Scotia; Drs. Neri Accornero, Vincenzo Tagliasco, and Pietro Morasso from Italy; Dr. Francis Lestienne from Paris, France; Drs. Roger Wales and Dianne Bradley from Melbourne, Australia; Drs. William Marslen-Wilson and Lorraine Tyler (principal guests of the Center for Cognitive Science) from Nijmegen, Holland; Dr. Melvin Konner from Harvard; and Drs. John Frisbee and John Mayhew, for two weeks, from Sheffield, England.

FACULTY

Although a report like this allows only a cursory description of the numerous services performed by our faculty members, some of their activities deserve more space than that of a mere statistic. Among these, Professor Walle Nauta's chairmanship of the FDA Aspartame Public Board of Inquiry, deserves special mention. All service combined, however, our faculty last year was represented on 15 national and international committees and boards and held 18 Institute committee seats. Beyond this, they accounted for more than a dozen editorial reviewer positions in the publishing world. Faculty, students, and staff published a total of 147 papers.

Our faculty members were equally in demand for colloquium presentations, lectures, and conference participations. More than 100 such commitments were honored between July 1979 and June 1980, taking them not only to numerous campuses and research institutes in the US, but to such foreign places as Tel Aviv, Nijmegen, London, Rome, Cambridge (England), Paris, Corsica, Berlin, Zurich, various places in Canada, and the 13th-century abbey of Royaumont, near Paris.

The past academic year saw a number of interesting developments and occasions. Noteworthy among these were the award to Dr. Emilio Bizzi of the Eugene McDermott Professorship in the Brain Sciences and Human Behavior (the first chair in Psychology at MIT), and his Alden Spencer Award from Columbia University; the Computer and Thought Award to Professor David Marr; and the professorial appointments for both Dr. Marr and Dr. Ann Graybiel. Professor Molly Potter's work on rapid reading, reported in "Parade" magazine, generated a good deal of public interest.

The Department's Colloquium committee was pleased to welcome its first speakers from mainland China: various collaborative efforts among the American Psychological Association, the Psychology Departments of Harvard University, the University of Michigan, and MIT, resulted in bringing Drs. Ching Chi-Cheng and Peng-den-Ling to our Department. Psychologists and educators from the Chinese Academy of Sciences, they came to this country as participants of the Sino-US exchange program.

Finally, the Independent Activities Period once again allowed us to present the by now traditional Art and Perception Symposium, which within its all-day format featured talks of interest to art historians, educators, psychologists, anthropologists, and those interested in visual science and space perception.

Reflections

In most respects, the past year was a good and fruitful one for the Department, but it had its share of sorrow in the tragic loss of one of our own: Jeremy Lanman died a mere week after receiving his doctorate this spring. He will be warmly remembered.

RICHARD M. HELD

Sloan School of Management

The major activities of the Sloan School continue to focus on research and on the education of both management professionals and of the educators of the next generation of management professionals as well as the researchers of tomorrow. Our undergraduate program, and primarily our Master's programs and the executive development programs, are our principal opportunities for affecting the quality and practice of management in this country and in others. Our doctoral program is aimed essentially at the training of future educators of management professionals and at training these persons to engage in the serious research which must underlie any successful efforts at professional education.

The following sections report on the Sloan School's programs, teaching, and research during the past year, and on the broad array of related professional activities in which the School's faculty and staff have engaged in that same period. Those activities continue to reflect the exceptionally high national and international rankings of the School's programs and its reputation for quality in both teaching and research.

As noted in last year's report, the School has developed and has begun to implement a plan which has as its objectives the building of a renewed uniqueness in the School's major programs, the strengthening of research in the School, and the enhancement of visibility and impact of the School's programs and research. The requirements for attaining these goals include the upgrading of the School's physical plant and the expansion of that plant. This will permit us to admit additional program participants in both our two-year Master's program and in our Senior Executive Program, and to improve the quality of student and faculty life and work at the School. The plan also calls for investments in additional faculty to staff these projected expanded enrollments and to permit a further expansion of research activities, largely sponsored, in many of the management fields taught at the School. The possibilities for new and expanded research activities are exciting, and provide the basis for the continuing evolution of strong teaching programs.

The plan also described the avenues for generating additional resources which would be required for the improvement of the School's programs, the expansion of its research, and for the fostering of better connections and stronger support organization for all of these teaching and research activities.

We have made some progress along a number of the investment dimensions described in the plan but have a way to go in meeting the physical plant needs -- which are an essential underpinning if we are to seize effectively the opportunities for continued and extraordinary success in the next decade. We are confident, however, that we will continue to make speedy progress in carrying forward these elements of the plan, because the problems of management in both private and public organizations continue to be a matter of major concern in all countries of the world, and the School's strengths are a major resource in helping the practicing professional to deal more effectively with these enormously complex challenges of our era. The several modest changes described in the plan, when taken together, can and will provide the basis for the continuing evolution of the Sloan School's strong programs and exciting research activities and, in turn, provide the basis for enhancing the School's significant impact on the quality and effectiveness of both the training and practice of managers in this country and elsewhere in the world.

TEACHING PROGRAMS

Undergraduate Program

The level of undergraduate enrollment in Course XV, including students who are pursuing double bachelor's degrees with other departments, remains high. During the 1979-80 academic year, 46 students received the Bachelor of Science in Management. Of these 21 were in Management Science, 5 in Behavioral Science, 2 in Dynamics of Management Systems, and 18 in approved Special Programs. Nine of the 46 also received additional degrees in science or engineering.

Our current enrollment would indicate that we will grant approximately the same number of S.B. degrees next year: 48 students with 21 in Management Science, 7 in Behavioral Science, 2 in Dynamics of Management Systems, and 18 in Special Programs. The year after that now appears somewhat smaller, although many members of the Institute Class of 1982 have not yet made definite decisions about Course choice. At the moment we have 26 students in that class: 14 in Management Science, 2 in Behavioral Science, 2 in Dynamics of Management Systems, and 8 in Special Programs.

This enrollment, taken together with the increasing number of MIT students from other departments who are electing Sloan School subjects, reflects a growing recognition of the need for managerial skills in diverse professional careers.

During the year, the Undergraduate Program Committee completed a two-year review of the curriculum requirements for all four programs, and implemented several changes in these curricula. Also during the year, we completed our resurvey with the American Assembly of Collegiate Schools of Business, which has recommended continuation of the School's accreditation.

One significant addition to the undergraduate program is the management game, which, until this year, had been available only in the graduate and executive programs. Its experimental run with undergraduates during the Independent Activities Period (IAP) was quite successful, and we expect to use it again each January.

The Student-Faculty Committee was visibly active during its first full year of existence. The students on the committee produced an undergraduate resume book, and investigated and reported on the resources available to them from both the MIT Career Planning Office and the Sloan School Placement Office. The group also carried out several social and fund-raising activities.

The program was chaired by Professor Jeffrey A. Meldman, with Esther Merrill serving as program coordinator. Professors Thomas J. Allen, Arnold I. Barnett, Gabriel R. Bitran, Stephen C. Graves, and Peter M. Senge served as undergraduate advisors, together with Professor Meldman and Ms. Merrill. Professor Hoo-min D. Toong served as the Sloan School's coordinator in MIT's Undergraduate Research Opportunities Program.

Professor Meldman, during his first year as Program Committee Chairman, has provided a vital stimulus in initiating many of these new curricular developments and in supporting the Undergraduate Student Association's efforts at enhanced participation in shaping them.

Master's Programs

The Master's Programs of the Sloan School continue to attract a large and well-qualified applicant pool. The past year 1,691 individuals competed for approximately 150 places in our two programs -- the Sloan Master's Program and the Accelerated Master's Program. This represents a 16 percent increase over the number of applications received in the previous year for the same number of student places. The increasing number of applications accentuates the need for ongoing improvement in the efficiency of aspects of our program administration such as recruiting, admissions, and so on, while the ever-rising quality of other major programs in management demands that we sharpen our academic excellence.

Academically, our programs continue to be solidly built upon discipline-based and functional studies which form the foundation upon which students develop their applied management skills at Sloan. The faculty also reviews the curriculum periodically to make certain that students are exposed to major critical issues of contemporary relevance to management. In recent years, core subjects in economics and marketing have been revamped, and the management game -- which has proved so useful in bringing together many of the theoretical and applied studies -- has become an important part of the curriculum. Discussion is now under way among faculty members of our accounting and finance disciplines concerning possible linkages which may make these studies even more relevant to the future professional needs of our students.

This coming year we are embarking upon a considerably expanded program in communication skills, both written and oral. Dr. JoAnne Yates, formerly of the Department of English at the University of North Carolina, has joined the Humanities Department at the Institute and will be spending much of her time working collectively and individually with Sloan School students. As the constituencies of organizations multiply and as communication among these constituencies becomes more frequent and important, the ability to express oneself has become an ever more important skill for managers to acquire.

The issues of breadth versus depth in our concentration options were considered this past year by our Master's Program Committee, which is composed primarily of faculty members. The delicate balance between these two goals makes consensus difficult to achieve, but a subcommittee has been formed and charged specifically with examining issues of redundancy and omission. The work of this committee should help us to review and redefine our management curricula.

In addition to progress in academic affairs, we are moving ahead in our efforts to professionalize our program administrative services. We are in the envious position -- vis à vis other major management schools -- of being able to involve our faculty and second-year Master's students significantly in the admissions process. This produces a student body whose interests and talents are consistent with the strength of our faculty -- a substantial factor in bringing the two groups closer together. The increasing number of applicants will necessitate some modification in the process, but we are committed to having our faculty and students play key roles in admissions decisions.

The ability of Master's students to finance their education through personal savings and existing loan programs appears less certain than in past years. As a result more students either are unable to attend Sloan for financial reasons or choose schools which provide more in the way of financial support. While we are able to fill the class with superior candidates, we are, nevertheless, concerned about those students who could benefit from a Sloan education but are prevented from doing so by the gap between available funds and the cost of a year of schooling. This is a concern which affects a substantial number of our students, but is most insidious in relation to the economically disadvantaged, who may have little in the way of personal resources and may have considerable indebtedness. It is an area which will receive our attention in the coming months.

The following data highlight some of the major characteristics of the Classes of 1980 and 1981 for both the Sloan Master's Program (two-year program) and the Accelerated Master's Program (calendar year program):

Characteristic	SMP		AMP	
	1980	1981	1980	1981
Sex: Female/Male	19/78	27/83	10/34	7/35
Age: Median/Range	25/21-37	24/21-35	27/22-36	28/23-37
Percent with Full-Time Work Experience	71%	74%	100%	100%
From: Countries/States	13/18	16/20	9/15	7/18
Mean Undergraduate Grade Point Average*	4.2	4.3	4.2	4.3
Median Admission Test Score**	616	624	618	628

*On 5.0 scale (excluding most foreign students).

** National average is approximately 460.

It was gratifying to see the percentage of women increase from 26 percent in 1979 to 29 percent for the Class of 1980. The median age for the Sloan Master's Program dropped by one year, whereas it increased by one year for the Accelerated Master's Program. The slightly older profile of the Accelerated Program represents an effort to identify candidates with greater work experience than those admitted in previous years. More states and countries are represented in the Class of 1980 than in the Class of 1979. Both undergraduate grade point average and median admission scores are slightly higher for the Class of 1980. Minority students (excluding Asian-Americans) represent 5 percent of the 1980 class, as was the case in 1979.

Efforts to attract qualified minority applicants to the School continue. In 1979-80, the School placed advertisements in a national black magazine, organized a presentation to minority undergraduate students at MIT, and initiated letter campaigns to minority college students with strong academic skills and a business orientation. In 1980-81 these recruiting efforts will be assisted by a half-time research assistant who is a minority second-year student at Sloan.

In 1979-80, the Placement Office expanded its staff and services. Paula Cronin (Class of 1977, Sloan School) serves as director and Wanda Jones, administrative assistant; Fran Gannon joined the office as secretary. In September, the office moved to a renovated classroom and adjacent office on the first floor of the Sloan Building. The enlarged space enabled the Placement Office also to become a fully functioning career resources library, a long-felt need of Master's candidates, employing organizations, and the Placement Office staff itself.

In the fall while recession was still more threat than reality, a record 175 organizations arranged to interview first- and second-year Master's candidates on campus for summer and permanent employment. As recession became reality, 25 organizations reassessed their needs and cancelled all their schedules; another dozen consolidated their schedules. While only one organization actually rescinded offers made and accepted, others visibly retrenched after the initial interview stage. The 1980-81 situation will require monitoring to assess the impact of further economic slippage on appropriate placement opportunities for our graduates and the actions which may be required by the office to help assure such opportunities. In the face of economic downturn, however, the mean starting salary for Sloan graduates hit a record high once again: \$32,200 (May 30 figure), up 13 percent from the 1979 mean of \$28,700. However, it is important to remember that this salary mean includes students with 0 to 15 years of work experience and a wide range of undergraduate and graduate concentrations. Moreover these students have accepted positions with employers running the gamut from governments of less developed countries (LDCs) to internationally recognized consulting firms. Thus the mean is inherently deceptive, and should not be regarded as a figure that all organizations must meet, or one to which all students are "entitled." Consulting firms once again led the offers, with a mean starting salary of \$43,800 (range \$24,000-\$56,000).

In 1979-80, the Placement Office extended its regular services -- vocational and personal counseling, on-campus interview schedules, on-campus company presentations, production of our annual Placement Report, production of a second-year resume book, maintenance and updating of correspondence opportunity files, company files, and current business periodical clipping files -- to include the preparation of a resume book of first-year students (mailed at no extra cost to the 224 subscribers to the second-year book), the development of two-day career management workshops (to be offered three times during 1980-81), and the arrangement of panel discussions by recent alumni/ae according to industry and function, including two sessions on interview techniques. These discussions will continue in 1980-81 and will be supplemented by visits from professionals in career management, particularly in the areas of identification and evaluation of career choices and the trade-offs faced by dual career couples.

The Placement Office has continued to respond to numerous requests from alumni/ae for help in making career changes. In the spring, these requests greatly increased, in part due to word-of-mouth news of the service and in part due to economic recession. In order to offer alumni/ae the best possible service, the Placement Office now refers these alumni/ae to the Director of Alumni Career Services in the Career Planning and Placement Office of the Institute, when appropriate.

Associate Dean Michael S. Scott Morton has continued to serve as chairman of the Master's Programs Committee and to give leadership to the committee's efforts at strengthening our Master's programs. The executive functions of the Master's programs are now under the very

able direction of Dr. Jeffrey A. Barks, director of Master's Programs, who joined Sloan from Dartmouth College where he was Assistant to the Vice President. Miriam Sherburne served as director of admissions and graduate registration officer, contributing her considerable knowledge of the Sloan School to both academic and administrative matters. Harriet Barnett, coordinator of Master's Programs, continued to provide her valuable administrative support for student-related services. Ms. Cronin and her staff have very effectively enhanced the School's placement service.

The Ph.D. Program

The mission of the Sloan School's doctoral program is to prepare men and women for academic and related careers emphasizing advanced research on management problems. The presence of a critical mass of doctoral students contributes in significant ways to the School's intellectual vitality and research productivity. Demand for Ph.D.s to staff the faculties of burgeoning collegiate management schools continues to exceed the available supply.

Competition among leading management schools for first-rate doctoral students is strong, and in 1979 the program had one of its most successful years on record in recruiting an entering cohort of 21 students. A total of 166 applications was received, a number that has remained constant for the past four years but somewhat below the peak levels of around 200 experienced in the early 1970s. Two-thirds of the 33 admitted entered the program in September 1979 -- the highest yield realized since 1971. This satisfying outcome was made possible by the School's commitment of additional funding to the doctoral program which enabled us to be more competitive with other management schools. The major fields of the incoming class were distributed as follows:

Accounting and Control	1
Applied Economics	1
Finance	1
International Management	2
Management Information Systems	4
Marketing	1
Management of Technological Information	2
Organization Studies	2
Operations Management/Operations Research	3
Strategy and Policy	2
Systems Dynamics	2
	<u>21</u>

In the 1979-80 academic year, seven Ph.D.s were granted in Management, a lesser number than the two previous years which reflects the smaller sizes of the entering classes in the mid-1970s. Four of these seven graduates received faculty appointments at Dartmouth College, Harvard University, Northeastern University, and the University of Ottawa.

Finding adequate funding to allow us to maintain a favorable position in the highly competitive market for new doctoral students remains as the program's most difficult problem. Additional School funds allocated to the program have enabled us to realize our goal of approximately 20 incoming students in each of the past two years. We now face the task of developing resources to support the program at this level on a continuing basis.

Professor Alvin J. Silk, chairperson of the Ph.D. Committee, together with Dean William F. Pounds and Associate Dean Peter P. Gil, have been actively pursuing further sources of support both inside and outside the Institute.

Alfred P. Sloan Fellows Program

On June 2, 1980, 56 Alfred P. Sloan Fellows were awarded the degree of Master of Science in Management. The Class of 1980 reflected a broad diversity of backgrounds and interests, and again was drawn from organizations from the United States and abroad.

A comparison of the Class of 1979-80 with previous classes follows:

	<u>74-75</u>	<u>75-76</u>	<u>76-77</u>	<u>77-78</u>	<u>78-79</u>	<u>79-80</u>
Industry						
US	29	21	25	26	31	30
Foreign	5	11	11	14	8	11
Government						
US	11	11	8	8	5	5
Foreign	1	1	1	5	2	1
Other						
World Bank	0	0	1	0	0	0
Municipal Management	1	1	1	0	0	0
Medical Management	0	6	6	2	6	6
Church Management	1	0	0	0	0	0
Research Institute	0	0	0	0	0	1
University Management						
US	3	2	1	0	2	1
Foreign	0	0	0	0	0	1
	<u>51</u>	<u>53</u>	<u>54</u>	<u>55</u>	<u>54</u>	<u>56</u>

The demand for the program continues to be strong and the quality of the nominations is extremely high. On June 20, 1980, the Class of 1980-81 arrived; there again will be 56 participants in the 1981 program. Countries represented in the program are Algeria, Argentina, Brazil, Canada, Denmark, France, Iraq, Israel, Japan, Panama, and the People's Republic of China. Almost 20 percent of the participants are women.

Professor Eli Shapiro continues as the faculty chairman for the Sloan Fellows Committee. Professor Shapiro will work closely with the director of the Sloan Fellows Program, Alan F. White. Mr. White is an alumnus of the program (Class of 1971). The program continues to be widely respected as one of the best executive education programs in the world.

Health Management Executive Development Program

The fifth year of operations was completed by the Health Management Executive Program as an integral part of the Alfred P. Sloan Fellows Program. There were six Sloan Fellows from the medical field. They were:

Joan G. Babbott, Physician Strategist, Planned Parenthood Association of Vermont, Inc., Burlington, Vermont

Richard D. Hansen, Administrator, Department of Obstetrics and Gynecology, Tufts University School of Medicine/New England Medical Center Hospital, Boston, Massachusetts

Aaron Joseph Kleinmann, Marketing Manager, Computer Systems Electronics for Medicine, Inc., Sudbury, Massachusetts

Benjamin C. Locke, Technical and Administrative Director, Renal Division, Peter Bent Brigham Hospital, Affiliated Hospitals Center, Inc., Boston, Massachusetts

Sister Mary Norberta Malinowski, Nurse Consultant, Felician Sisters of the Order of Saint Francis, Enfield, Connecticut

Ann S. Peterson, Associate Dean for Student Affairs and Associate Professor of Medicine, College of Physicians and Surgeons, Columbia University, New York

The program is co-directed by Professor Edward B. Roberts and Mr. White.

Program for Senior Executives

The 48th and 49th sessions of the MIT Program for Senior Executives were held in 1979-80. The 60 men and women who participated in the program were drawn primarily from private industry in the United States. Approximately 20 percent came from abroad. There are now over 1,000 alumni who occupy positions of leadership in many companies and organizations around the world.

Demand for the limited number of spaces in the program remains high.

Professor Arnaldo C. Hax served as chairman of the program's faculty committee, and Dr. Scott Duncan is the new program director.

Greater Boston Executive Program (GBEP)

The 23rd session of the Greater Boston Executive Program was held from January 25 to May 9, 1980. The program continues to enjoy strong support from a number of organizations in the Greater Boston area. There were 18 participants and their detailed evaluation of the course was enthusiastic.

To encourage participation by member firms of the Massachusetts High Technology Council, the program's Administrative Committee added two new members representing the High Technology Council: Dr. Russell W. Olive, Vice President of Human Resources, Analog Devices, Inc.; and Bernard J. Rudman, Consultant, Massachusetts High Technology Council.

The alumni reunion on May 1, 1980, as in past years, was well attended.

James Gabbert continued to provide very capable coordination for the program.

Summer Programs

Sloan School faculty offered 14 of the Special Programs in the MIT 1979 Summer Session. Eleven of these were on topics that have been offered for several years and they continued to attract large numbers of professional men and women who want to keep up with new developments and techniques in the fields covered.

Professor Edward B. Roberts was in charge of the two-week program, Management of Research, Development, and Technology-Based Innovation, and of the one-week session on The Dynamics of Health Service Systems. Professors Richard Beckhard and Edgar H. Schein offered the one-week live-in program at Endicott House on New Horizons in the Management of Change and Organizational Development.

Professor Jay W. Forrester and other members of his group offered the two-week program on Corporate and Economic Policy: The System Dynamics Approach.

Professor Stewart C. Myers of the Finance Group presented the two one-week programs on Modern Concepts in Financial Management and Models for Financial Management and Long-Range Financial Planning. Professor Gerald A. Pogue of Baruch College, The City University of New York, assisted him in both sessions.

The Management Science Group offered new versions of five programs that had been given in previous years: Information Systems Technology -- Database Systems, Telecommunications, and Performance Evaluation and also Advanced Software Concepts -- Operating Systems, both presented by Professors John J. Donovan and Stuart E. Madnick; Project Design for EDP Applications (Professor Robert M. Alloway); Strategic Planning Systems (Professors Hax and Peter Lorange); and Management Control Systems (Drs. J. Morrison McInnes and John F. Rockart, Associate Dean Scott Morton, and Professor Michael F. van Breda).

Three new programs were added in 1979. Professors Jeremy F. Shapiro and Eduardo M. Modiano offered a one-week seminar on Energy Planning Models. The purpose of the program was to discuss how quantitative models and methods have been used to study long-term energy planning policies and to evaluate the answers they have provided.

Professor Hax chaired a program on Modern Practice in Production and Distribution Management. He was assisted by Professors Bitran and Graves and Senior Lecturer Harlan C. Meal. Sessions were devoted to such topics as Strategic Planning and Manufacturing Policy, Facilities Planning and Industrial Project Evaluation, Aggregate Production Planning, Aggregate Inventory Management, and Organization Design and Information Systems.

Professor Zenon S. Zannetos directed the third new program -- Corporate Strategy and Policy. This short course was designed to meet the needs of top-level executives, and dealt with the theory and methodology applicable to corporate strategy development, with methods of structuring external and internal environments of the firm in order to identify opportunities for action, and with methods of strategy implementation and control for evolutionary adaptation. Principal lecturers, in addition to Professor Zannetos, were Professor Edward H. Bowman of the Sloan School and Professor Russell L. Ackoff of the Wharton School, University of Pennsylvania.

These new programs were all well attended and two of them are scheduled to be given again in the 1980 Summer Session.

In addition to these programs offered as part of the Institute's Special Summer Programs, members of the faculty and staff directed and participated in three other summer seminars. The Center for Information Systems Research offered its fourth summer program devoted to Current Issues in Information Systems with a new format of general and elective sessions and at a new place, the Cambridge Hyatt Regency Hotel. Members of the marketing faculty presented the third annual three-day symposium on Marketing Science: New Developments and Current Practice. Finally, Professor J.D. Nyhart, who holds dual appointments in the Sloan School and Department of Ocean Engineering, participated in the sixth Harvard Law-MIT Seminar on Ocean Use and Policy.

Industrial Liaison Symposia

Two of our faculty directed symposia for the Industrial Liaison Program this past year. In February, Professor Thomas L. Magnanti chaired a one-day program on Distribution Planning, System Design and Management, and in April Professor Zannetos was chairman of another one-day program on Corporate Strategy and Policy.

Once again these summer and liaison programs, although designed to offer specific post-experience training to professional managers, continue to help the faculty make substantial improvements in our year-round degree and residential programs by serving as "proving ground" for curriculum review, innovation, and redesign.

RESEARCH

The research interests of the School's faculty, staff, and students are extensive. The volume of sponsored research support at the Sloan School is substantially larger than at most of the major management schools in the country -- almost \$2 million during fiscal year 1980. These research interests are also diverse and changing.

This section summarizes the major research efforts and accomplishments of the School. This work is both disciplinary and multi-disciplinary 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 employment and industrial 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, on managers, and on some urban workers, plans are developing for a broader, comparative longitudinal approach to a wider range of occupations and organizations. The goals are 1) to better understand how organizations develop their socialization practices and how such practices reflect organization culture; 2) to better understand how the socialization practices lead to patterns of productivity, creativity, job satisfaction, and accommodation among different life concerns; 3) to improve the activities of human resources planning and career development within organizations; and 4) to help individuals to plan more productive and satisfying lives.

Professor John E. 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 Lotte Bailyn is continuing her study of accommodation patterns in educated adults, especially in dual-career families. Professors Bailyn and Schein have finished a major report of their alumni survey of the MIT Classes of 1951, 1955, and 1959 which analyzes career patterns and the nature of work involvement in this technically trained group of people now at mid-life. This report will be published by the MIT Press and is entitled "Living with Technology." Professor Bailyn is continuing work on technically based careers and is now conducting follow-up research of some of the alumni to determine further adaptation patterns.

Professor Ralph Katz is continuing his analysis of the determinants of job satisfaction, especially as a function of career variables such as the number of years the employee has been on a given job (job longevity). Professor Katz has extended this work to an examination of productivity and commitment both in individuals and groups as a function of job longevity, and is in the third major year of a project on research and development groups. 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.

The work on career development is increasingly connecting with the second major research area in the Organization Studies Group conducted by Professor Allen. Professors Allen, Katz, and their colleagues, Professors Roberts and von Hippel, continue to unravel the factors which aid or hinder the process of innovation and technology transfer.

Though the research efforts of individual faculty members continue to be largely guided by the requirements of their own projects 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. Several members of the faculty and staff are engaged in this kind of action research. Professor Richard Beckhard and Dr. Edwin C. Nevis are continuing to pursue a variety of planned change and organization development activities.

Professor Beckhard is focusing on the effects of different kinds of planned change interventions, especially in large and complex systems. Dr. Nevis continues to work on factors relating to creativity. Professors Beckhard and Schein also have begun a study of the family firm in an effort to unravel the complex factors which shape the evolution of family businesses.

Professor Leo B. Moore is currently examining the impact of a Management by Objectives Program on an organization, making a full-scale audit of a Management Development Program, bringing an Assessment Center to implementation, and initiating an integrated Human Resources Program.

Employment and Industrial Relations. Faculty members of this area have continued research mentioned last year, and begun some new projects during the past academic year. These indicate the breadth and changing nature of research in this field. With the full-time appointments of Professors Robert B. McKersie (who was visiting during the past year) and Thomas A. Kochan, along with Assistant Professor Katharine G. Abraham, research during the coming year will take additional new directions.

Professor Phyllis A. Wallace, who was acting director of the Industrial Relations Section during the spring term, continued her research on upward mobility of women by surveying and interviewing graduates from the Master's program for the Classes of 1975 through 1979. Women graduates have been matched with male peers and data will be collected from both groups over a five-year period. Thus far, one-year follow-up interviews have been conducted for the Classes of 1975 through 1979, and two-year in-depth interviews have been conducted for the Classes of 1975 through 1977. During the coming summer, the Class of 1975 will be asked to participate in a detailed five-year follow-up survey.

One of the primary objectives of the research is to chart how young managers, particularly women, move into middle management. A significant preliminary finding is that two years after Sloan School the women have done as well as the men, if one measures success in terms of salary increases, bonuses, promotions, performance appraisal, and job satisfaction. But the psychic costs for women may have been greater. The Sloan School funded a research assistant during the past academic year on this project, and a small grant was received from the Millipore Corporation, as one had earlier from General Motors. A major concern remains obtaining additional funding.

In addition to this major research, Professor Wallace has continued her work on "Dynamics of the World of Work," which is an attempt to link employment policies (internal and external to the firm) to issues related to employment discrimination. She also has been working (with Professor James W. Driscoll as coauthor) on a chapter entitled, "Social Issues in Collective Bargaining, 1950-1980: A Critical Assessment," for an Industrial Relations Research Association volume, "US Industrial Relations, 1950-1980," to be published late in 1981.

Finally, Professor Wallace is editing the papers presented at an earlier Industrial Liaison Symposium which she organized on "Women in the Workplace: Management of Human Resources." It will be published by Auburn House, Boston, sometime in 1981. During the year, her book, *Black Women in the Labor Force*, was completed for MIT Press publication in July 1980 and two Sloan School Working Papers were prepared on other topics.

Visiting Professor McKersie left early in April to undertake research in Great Britain and in other European countries on "Public and Private Policies for Preventing and Cushioning Large-Scale Redundancies." This is being funded by the Ford Foundation. Professor McKersie will be continuing this study when he returns.

Professor Thomas A. Barocci has completed his part of the major research project on "Private Investment, Public Policy, and the Transformation of Older Regions: An Analysis of the New England Economy." This was funded by grants from the Departments of Commerce, Labor, and the former Health, Education and Welfare (HEW) to a larger group of researchers through the Harvard-MIT Joint Center for Urban Studies. Under his supervision, reports on the electronics, paper, commercial printing, and grocery industries were carried out, with the help of graduate research assistants who completed theses. One also helped him on his study of the hospital industry in New England. A manuscript on this topic is being revised for publication this fall, under the title, "Non-Profit Hospitals: Their Management, Workforce and Economic Importance," Auburn House, Boston.

Other hospital research by Professor Barocci extends beyond the New England project to an exploration of the economics of scale in hospitals and the impact of technological changes and unionization on labor force requirements. Some of this work will be incorporated in the book already mentioned; some into a chapter, "Collective Bargaining Among US Physicians," in a forthcoming 1981 British volume, "Industrial Relations and Health Services."

Professor Barocci also has continued his research on employment and training policies. He is working for the Brookings Institution on tracking Federal construction dollars through local labor markets; and in conjunction with Westat Corporation, he is continuing research on the use of the Continuous Longitudinal Manpower Sample in the evaluation of employment and training programs. His earlier study, *Public Works, Government Spending, and Job Creation: The Job Opportunities Program* (with Robert Jerrett, III), was published by Praeger Publishers, New York, in fall 1979. A Sloan School Working Paper, "Disinvestment in Massachusetts: A Case Study of Personal and Economic Impacts," was also completed last fall.

Professor Driscoll has been supervising a research project to evaluate the effectiveness of the Scanlon Plan, which has had a long association with the Industrial Relations Section. Funds from a number of Scanlon Plan companies contributed to the Section to finance this research. Professor Driscoll and his student research assistants have gathered information from seven Scanlon Plan companies and a matched set of seven other plans. Data has come from questionnaire descriptions of the quality of work life; financial information on productivity; and questionnaire and interview information on labor relations and the union's effectiveness. Much of this work will be completed during the summer and fall. A preliminary article, "Working Creatively With a Union: Lessons from the Scanlon Plan," appeared in the American Management Association's *Organizational Dynamics* in summer 1979.

Professor Driscoll also has been doing research on office automation, looking at electronic message systems from a management point of view. He has visited eight innovative users of computer-based office systems, and in cooperation with other MIT colleagues has surveyed in-house research conducted by nine large users of office automation. One article on this area of research, "The Redesign of Office Work: A Behavioral Science Perspective in Office Automation," will appear in *Datamation* soon. A Marshall Fund grant has made possible a trip in June to compare approaches to automation in a number of Western European countries.

A number of journal articles on Professor Driscoll's earlier research on union-management cooperation, problem solving in labor relations, and other topics will appear under the following titles: "Coping with Role Conflict: An Exploratory Field Study of Union-Management Cooperation" and "Problem-Solving Between Adversaries: Predicting Behavior in Labor-Management Committees" (both in the *International Journal of Applied Psychology*); "Success and Failure in Labor-Management Panels" (*Monthly Labor Review*, US Department of Labor); and "Human Resource Planning: A Decision-Making Approach" (*Human Resources Planning*). Several other articles with coauthors have been published or are forthcoming in other journals. A Sloan School Working Paper, "Office Automation: The Dynamics of a Technological Boondoggle," has been completed.

Professor Harry C. Katz is expanding his research on the operation of wage rules, along with two colleagues at MIT and at Harvard. He presented a paper, "Wage Rules: A Theory of Wage Determination" (with Charles Sabel), at the Allied Social Science Meetings in Atlanta in December, and the new effort is to provide empirical support for the theory by analyzing recent wage settlements in the auto, rubber, and steel industries. Professor Katz also has been engaged over the past year and a half in research on the interaction of labor relations and the desegregation process in the Boston public schools, and he proposes to expand this to seek comparative information from the experience of other school systems undergoing desegregation. A grant application to the National Institute of Education (HEW) has been made.

Two other research projects have engaged Professor Katz's attention. He has been working with Professor David Lewin of Columbia University on the public sector wage determination process, and a joint paper will be presented at the annual Industrial Relations Research Association Meetings in September. He also has continued his involvement with a research project through Boston University's Regional Manpower Institute on rural labor markets in Maine. His paper on the position of government in the Maine economy will appear in a larger volume now being prepared for publication.

Professor Katz's publications during the past academic year included: "The Municipal Budgetary Response to Changing Labor Costs: The Case of San Francisco," *Industrial and Labor Relations Review*, July 1979; and "Interest Arbitration, Outcomes and the Incentive to Bargain: The Role of Risk Preferences" (with Henry S. Farber) in the same journal, October 1979. His University of California at Berkeley Ph.D. dissertation, "The Impact of Public Employee Unions on City Budgeting and Employee Remuneration--A Case Study of San Francisco," will be published by Garland Publishing Company in 1980 in its series of distinguished dissertations in economics.

In addition to his joint research with Professor Katz, Professor Henry S. Farber (Department of Economics) is working on an analysis of different types of arbitration as they affect the incentive to bargain and outcomes of negotiations. This includes an empirical study of final offer arbitration decisions. Other research is centered on the role of seniority on the propensity to quit; on relative wages and union membership including an analysis of queuing for union jobs; an analysis of wage indexation, wages, and contract length; an analysis of optimal employer offers and learning in the context of a simple model of bargaining; and the interrelationships between public sector bargaining laws and strike activity.

In addition to the joint published paper with Professor Katz, Professor Farber's papers during the past year include: "Why Workers Want Unions: The Role of Relative Wages and Job Characteristics" (with Daniel H. Saks), "Journal of Political Economy" (forthcoming); and "Unionism, Labor Turnover and Wages of Young Men," presented to the Secretary of Labor's Conference on the National Longitudinal Surveys of Young Men and Young Women, March 1979, to be published in "Research in Labor Economics," Vol. III, 1980.

Senior Lecturer Stanley M. Jacks has been interested in labor law questions, particularly US Supreme Court decisions affecting labor relations and affirmative action. Emeritus Professor and Senior Lecturer Charles A. Myers has concluded most of the research and writing (with his coauthor Professor Emeritus Paul Pigors) for the ninth edition of *Personnel Administration*. This will be published by McGraw-Hill late in 1980.

Economics and Finance

The Economics and Finance Group is the second basic disciplinary area on which the School's research and teaching programs are built.

Professor Sidney S. Alexander has once again been on leave for the major portion of the past academic year, primarily engaged in consultation in the antitrust field. He has continued during the portion of his time at the Sloan School to work on the social foundations of economic policy.

Professor Daniel M. Holland has continued his research together with Professor Myers on corporate profitability and capital costs. A paper reporting their recent work in this area appeared in the May 1980 issue of the *American Economic Review*. Professors Holland and Myers have also been continuing their analysis of the links between returns to investors in corporations and the returns corporations make on their investments. With funding from MIT's Project on International Business, they have assembled a group of scholars who represent 10 countries, all interested in working together to develop measures of rates of return to capital that could be compared over time within each country and across countries. Professor Holland also has continued to work on the tax problems of Massachusetts and the City of Boston with Oliver Oldman of the Harvard Law School. Professor Holland also continues to serve as editor of the *National Tax Journal*.

Professor Edwin Kuh has continued his research in conjunction with others at the School's Center for Computational Research in Economics and Management Science, and has focused on the area of model reliability. Essentially Professor Kuh's work focuses on the system properties of econometric models when they are subject to parameter perturbations, and provides a set of powerful tools for the analysis of model behavior. Some of the results from this work have been described in a book, "Regression Diagnostics: Identifying Influential Data and Sources of Collinearity," co-authored with David Belsley and Professor Roy E. Welsch, to be published this year by John Wiley & Sons. Professor Kuh also spent several months last fall in Paris working with French colleagues on issues of model reliability at Centre d'Etudes Prospectives d'Economie Mathematiques Appliquees à la Planification (CEPREMAP).

Professor Franco Modigliani has continued to pursue work in the broad area of the monetary mechanism, stabilization policies, and the problems of macro rational expectations. One of the initial outcomes of this research will be a paper to be presented in October at a conference at the Federal Reserve Bank of Boston. Professor Modigliani has also pursued a number of issues leading to the impact of inflation on financial markets, and in particular has been developing extensive tests on the effect of inflation on the valuation of shares relying on cross-sectional data. Finally, Professor Modigliani has been analyzing a number of factors, such as inflation and social security, that might influence aggregate saving behavior. He continues to serve on the Brookings Panel on Economic Activity, and also has been vice president of the International Economic Association.

Professor Robert S. Pindyck continued his work on the economics of resource exploration and production, the effects of uncertainty on the behavior of the firm, and on several general questions dealing with energy policy. Professor Pindyck's work on resource economics has focused on the linkages between optimal rates of exploration and production, and on the effects of uncertainty on the behavior of resource markets. He has written a paper analyzing the conflicts involved in US energy policy, and has conducted research on the macroeconomic impacts of rising energy prices. Professor Pindyck also has written a paper analyzing the effects of uncertainty over product demand on the investment and production decisions of the firm.

Professor Thomas M. Stoker's principal research areas were aggregation theory and consumer demand analysis. He wrote a paper which studies the use of survey data in characterizing macro-economic relations, and which connected theories of aggregation in economics and statistics. Professor Stoker also worked on an empirical model of US consumer demand in collaboration with Dale Jorgenson of Harvard University, and used the model to evaluate the welfare impacts of governmental policies on different types of families. Professor Stoker also has worked on the estimation of the model's parameters subject to the tenets of utility theory, in order to facilitate linking the model to a model of the US production sector, and thereby allowing simulation of US economic activity.

Professor Richard Schmalensee continued his work on public policy toward commercialization of new energy supply technologies such as synthetic fuels. In a paper on the subject published in *The Energy Journal*, Professor Schmalensee argued that proposals to subsidize particular new technologies have rarely been supported by sound economic arguments. In addition, he published papers on optimal management of renewable resources and markets for nonrenewable resources, and he completed two essays on the theory of price discrimination. With support from the US Federal Trade Commission, he has been studying the operation of markets in which buyers cannot easily judge quality prior to purchase, markets in which trademarks therefore become important. Professor Schmalensee continues as editor of the MIT Press series on regulation of economic activity and as a member of the editorial board of the *Journal of Industrial Economics*. He also has served as program chairman for the 1980 North American winter meeting of the Econometric Society.

Professor Lester C. Thurow spent the past year on leave working on the editorial board of *The New York Times* and at the University of Arizona. His recent publications include a new book -- *The Zero-Sum Society* -- and academic articles on "A Theory of Groups and Economic Redistribution," "The US Productivity Problem," and "The Indirect Incidence of Government Expenditures." Professor Thurow is continuing his research work on productivity and the incidence of government expenditures.

Professor Martin Zimmerman has continued to work on issues relating to US coal supply and policy, and completed a book entitled "The US Coal Industry: The Economics of Policy Choice" to be published next fall. With funding from the Center for Energy Policy Research of the MIT Energy Lab, Professor Zimmerman continued to work on electric utility technology adoption, and coauthored a paper entitled "What Happened to Nuclear Power: A Discrete Choice Model of Technology Adoption." In addition, Professor Zimmerman has continued to work on issues related to the taxation of coal production, and on the economic interpretation of coal resource estimates.

Professor Carliss Y. Baldwin's principal research interest has been in the allocation of human and financial capital in a corporation, industry, or economy. The main areas of investigation are 1) optimal investment policies for long-lasting assets when future opportunities are unknown, 2) optimal investment policies for participants in imperfect markets, and 3) the effect of difficulties in enforcing contracts on long-term investment decisions.

A paper, "Liquidity Preference Under Uncertainty: A Model of Dynamic Investment in Illiquid Assets" (with Richard F. Meyer), was published in the *Journal of Financial Economics*, December 1979. A second paper, "Optimal Long-Term Investment When Price Depends on Output," examined sequential investment in a concentrated industry and is currently under revision.

In May 1980, Professor Baldwin was awarded a two-year faculty fellowship from the Bunting Institute of Radcliffe College. The fellowship will provide support for further research on irreversible investments.

Professor Fischer Black has finished a revised draft of his paper on business cycles. He believes it is possible to explain business cycles as a natural result of freely operating markets for goods and services and for capital and labor. That means there is nothing the government can do to make the economy work better by reducing the magnitude of business fluctuations. Monetary and fiscal policies are generally ineffective, while policies that do dampen fluctuations will slow the growth of the economy.

He also is working on a theory of accounting, centering on rules for computing earnings. Economists like to think of a firm's earnings over a year as representing the change in the firm's value over the year, while financial analysts like to think of a firm's earnings as proportional to the firm's value at the end of the year. Professor Black feels that the financial analysts' view is close

to the way earnings are normally computed, and that there is no practical way to apply the economists' view of earnings.

Professors Holland and Myers continued their research in corporate profitability and capital costs. They broke out the manufacturing sector from the broader non-financial corporation aggregate that they studied earlier, and they are now able to analyze manufacturing -- a more homogenous group -- in the same way they did all non-financial corporations. A paper reporting their results was presented at the annual meeting of the American Economic Association in Atlanta in December. It was published in the May 1980 issue of the *American Economic Review*.

The work Professors Holland and Myers are doing is the US effort in the MIT Rate of Return Project -- a project Professor Holland has directed for about five years. With modest funding from MIT's Project on International Business, the project has attracted a group of scholars who represent 10 countries, all interested in working together to develop measures of rates of return to capital that could be compared over time within each country and, we hope, across countries as well. After some "backing and filling," the project has jelled, and Professor Holland reported last year the planned publication of a volume incorporating the group's research.

In June, Professor Holland presented a paper at the annual meeting of the Western Economic Association that will be a further extension of his research in profitability and capital costs in that it breaks out a non-manufacturing non-financial corporate sector, thus providing three "universes" of profitability observations -- all non-financial corporations and the two sectors that make up this aggregate: manufacturing corporations and non-manufacturing non-financial corporations.

Professor Oliver Oldman (Harvard Law School) and Professor Holland have continued their work on Boston's tax and expenditure problems.

Professor Holland also has worked as an advisor on one phase of Professor J. D. Nyhart's deep ocean mining project. The area he has been involved with is the development of the relevant tax characteristics and estimates of tax liability under the laws of a number of different countries; the objective is to understand how importantly the "intrinsic" profitability of a proposed deep sea mining venture is affected by the country it is taxed by.

Professor Donald R. Lessard, with the support of a Tinker Foundation Fellowship, has continued his research on financial mechanisms for shifting commodity price risks from less developed countries (LDCs), which are producers to the capital markets of industrialized countries. In particular, he has analyzed the potential of commodity-linked bonds and risk-shifting participation contracts as alternatives to commodity price stabilization mechanisms. He also has completed working papers on two aspects of international corporate financial management -- foreign exchange risk management and capital budgeting.

In a new line of research, Professor Lessard has completed a working paper on public enterprise finance in LDCs which shows that the way such enterprises are financed is likely to affect their strategic and operating decisions. The paper also provides some preliminary normative guidelines for public enterprise finance. This research, which has been conducted jointly with Malcolm Gillis and Glen Jenkins of the Harvard Institute of International Development, is now being extended to an empirical study of public enterprise finance in Indonesia, Malaysia, and Colombia.

Professor Modigliani's research has been devoted toward pursuing three main areas in which he has been interested for some time. First, he continued to work in the broad area of the monetary mechanism, stabilization policies, and the problems of macroeconomic rational expectations. A research proposal was submitted to the National Science Foundation jointly with Lucas Papademos of Columbia University, and a two-year grant has been approved. One of the initial outcomes of this research will be a paper to be presented at an October Federal Reserve Bank of Boston conference on controlling monetary aggregates.

Second, Professor Modigliani has studied the impact of inflation on financial markets. In particular, he has been developing fairly extensive tests (based on cross-sectional data) of the effect of inflation on the valuation of shares. These tests aim at supplementing and providing evidence on the undervaluation hypothesis, advanced with Richard Cohn, and tested initially with time series data.

Finally, he has analyzed the factors influencing aggregate saving behavior within the framework of his life cycle hypothesis. These factors include inflation, social security, and the role of bequests. A paper focusing on the effect of social security and tests based on a cross section of countries has been completed in collaboration with Arlie Sterling and presented at the conference of the International Economic Association held in Bergamo, Italy in June.

As noted earlier, Professor Myers has continued his joint research with Professor Holland on trends in profitability and capital costs for US manufacturing corporations. He also has begun research in two new areas, the long-run impacts of inflation within the current system of public utility regulation, and the potential role of futures contracts written on stock market indices.

Finally, Professor Robert C. Merton has continued his research in finance and economics in the areas of capital markets, asset evaluation, information evaluation, and corporate liabilities pricing. In addition to continuing his research in these areas, his most recent work has been concerned with the latent functions of capital markets as sources of information for decision making, estimation of the expected return on the stock market, market timing and investment performance, and the determination of the equilibrium value of nonpublic information. He has received support for his research from a National Science Foundation grant and also from the National Bureau of Economic Research.

Management Science

The Management Science Group, the third of the Sloan School's principal foci of teaching and research, 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 divided into context-related research that deals with specific areas of management concern and into methodological research on general tools and techniques. The application contexts can be further subdivided into public and private sectors.

Energy continues to be a major focus in the public area. The work is heavily interconnected with other parts of the Sloan School and of MIT, particularly with the Energy Laboratory. Professor Henry D. Jacoby is director of the International Energy Studies Program of the Energy Laboratory and also director of the Center for Energy Policy Research. Professor Jacoby has been particularly concerned with the analysis of the world oil market and its implications for US energy policy. A further concern is assuring uranium supplies. Professor Gordon M. Kaufman is developing methods for predicting future supply of energy minerals as a function of policy choice, process, and regulatory regime. He has supervised an extensive project to model the process of oil and gas exploration, and has developed methods to permit better estimates of undiscovered oil and gas reserves. Professor Gary L. Lilien has been working with the photovoltaics program of the Energy Laboratory to develop and apply a model for assessing the impact of government purchase and demonstration programs on the timing and level of penetration of a new technology. A further study is in progress to investigate the tradeoffs between government investment in research and development and in demonstration programs. Senior Lecturer David O. Wood has been active with a wide variety of energy research including a significant effort in the area of energy model assessment. Senior Lecturer Gordon F. Bloom has been concerned with energy conservation in supermarkets where refrigeration accounts for substantial national consumption. Dr. Meal's study of geothermal energy for industrial use is leading to a general analysis methodology for the design of energy cascade in multiple process manufacturing plants.

Several faculty are working on issues in transportation management. Professor Barnett's paper on airline safety records has drawn international attention. Professor Magnanti has been investigating the use of large-scale optimization techniques in network problems, particularly rail freight management and urban traffic equilibria. Professor John D. C. Little has completed a project extending the scope of maximal bandwidth methods for setting traffic signals.

In other public sector activities, Professor Barnett has continued his examination of the deterrent effect of capital punishment. Professor Richard P. Bagozzi is studying the relation between intentions to give blood and subsequent donation.

In the private sector a variety of work has been going on, especially in the areas of marketing, operations management, and planning and control. The marketing faculty continue their well-known work in marketing models and measurements. Professor Glen L. Urban is developing and testing hierarchical models of consumer choice that define market structure and lend themselves to product strategy analyses. Professor Silk continues his work on measuring influence in organizational purchase decisions. Professor Little is exploring the marketing measurement capabilities of point-of-sale data collected automatically through the Universal Product Code system. He and students working with him have several new results. For example, they can distinguish between customers' response to normal shelf price changes and their response to varying the level of price reduction during special promotions. Professor Manohar Kalwani is analyzing market structure by means of product segmentation.

Professors Little and Silk are participating in an ambitious controlled field experiment to test the relative effectiveness of two alternative advertising strategies. The breadth and scale of measurement are unusual and include detailed time series sales data from 28,000 households and attitudinal data from 15,000. The measurement precision being attained is unprecedented in advertising field experiments.

An important and long-neglected research area in marketing concerns industrial products, i.e., those sold to organizations rather than individuals. In the past few years the marketing faculty has initiated a significant research effort in this direction. Of particular interest is the sales force since it represents the greatest part of industrial marketing expense. Professor Bagozzi is completing a major study on modeling the determinants of sales force performance and satisfaction. Professor Urban is developing industrial product selling laboratory techniques to measure the impact of industrial selling and advertising messages. Professor Urban is also director of the Marketing Center, which coordinates sponsored research in the area.

We are pleased to note that for the second year in a row the Alpha Kappa Psi Award for the best paper in the *Journal of Marketing* has gone to a member of the Sloan School marketing faculty, this time to Professor Little for his paper, "Marketing Decision Support Systems."

Although management science techniques have long been helpful to companies in designing production and logistics systems, developers have tended to compartmentalize problems into small systems that really should be connected into large ones. At the same time, large systems have often collapsed because of difficulties in maintaining them. Professors Hax and Bitran are engaged in a continuing project on hierarchical production and distribution systems which seeks to tackle these issues. In their work, models for higher level strategic decisions set constraints for more local tactical decisions from which the latter feed back information to the former. Dr. Meal has developed a simulation of a multiple stage production control which can be used to evaluate hierarchical methods. Professor Graves has been working on further production and inventory planning problems and, in addition, has been studying control and design decisions for adaptable-programmable assembly systems, popularly known as industrial robots.

Professor Hax also has become heavily engaged in developing formal planning systems. His research includes design and implementation methodologies and empirical research in the field of mergers and conglomerates. Dr. McInnes and Professor van Breda are doing research in financial control systems. They have surveyed 21 companies concerning practices in financial planning and control. This work will lead to a typology for describing what types of models and systems are useful in what kinds of settings. Professor Peter Brownell has completed research on managerial participation in the budgeting process and its relation to locus of control and organizational effectiveness.

Mathematical programming is one of the major methodological thrusts within the group. Many large-scale systems are potentially capable of improvement by these techniques. A surge of theoretical developments in recent years is being integrated into practice by introducing better computational support and adding needed extensions to the theory. Professor Shapiro has been supervising the development of a modular system of mathematical programming packages. He also has focused research effort on certain outstanding issues in integer and mixed integer programming, particularly with respect to new methods based on duality. Professor Magnanti has been attacking problems in combinatorial theory and nondifferentiable optimization. Professor James B. Orlin is also working in combinatorial optimization with special attention to scheduling problems in which the schedules repeat periodically over time.

One effect of the computer revolution is a deluge of data. This is stimulating new directions in statistics. One important issue is the distortion of estimation and inference by "bad" data. Professor Roy E. Welsch has been developing robust nonlinear regression techniques to alleviate some of these difficulties. In addition he has focused on the most widely used multivariate techniques, multiple linear regression, and has been developing new kinds of diagnostics for understanding the statistical properties of the results. Professor M. Anthony Wong is studying techniques for clustering, a ubiquitous data analysis task.

Computer-based information systems are a permanent fixture on the managerial landscape. An important concept in the field had its inception and has its principal articulation within the Sloan School. This is the area of decision support systems to assist managers and policy makers. Professors Scott Morton and Peter G. W. Keen have pioneered the definition and elaboration of this idea. Professor Donovan, in a cooperative effort involving the March of Dimes and Tufts University, has developed a birth defects information system which exemplifies these concepts.

In other work Professor Madnick is pursuing basic research on database computers with the goal of extending their capability by orders of magnitude. Professor Meldman has been concerned with 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. Professor Toong is studying microprocessor technology, its potential effect on production and managerial processes and ways in which bottlenecks in microprocessor architecture can be overcome. Professor M. Lynne Markus is assessing the organizational impacts of management information systems.

The importance of computers and computerized decision support systems is further reflected in the activities of the Center for Information Systems Research (CISR), directed by Senior Lecturer John F. Rockart. CISR 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 has organized highly successful seminars on current issues in information systems research. Dr. Rockart himself is engaged in the study of the information needs of top management. His technique of eliciting from managers a set of critical success factors for their organization has enabled the building of information systems much more responsive to managerial needs. Under CISR sponsorship Professor Alloway has been conducting a field study of the end-users of data processing at all levels and developing a much-needed understanding of user requirements.

Finally we note that during the past year, our faculty have been active in many professional society roles. In particular Professor Little has held the position of president of the Operations Research Society of America.

System Dynamics

The evolving structure of the System Dynamics National Model now includes a capital sector, a consumer durables sector, a household-consumption sector, labor movement between sectors, wage and price setting, money flows, and long-term and short-term borrowing and interest rates. Priority research issues include inflation, long-wave behavior, and energy policy.

The national debate on inflation has in the past comprised several simultaneous processes of price change. These can be separately studied with the National Model. Prices rise and fall reversibly over the three- to seven-year business cycle. They rise and fall reversibly with the inflationary and deflationary phases of the economic long wave extending over 45 to 60 years. Internal economic stresses can cause a one-time rise in prices, but not continuing inflation. Such stresses can be generated by factors like oil price increases, union bargaining power, acquiescence by management to increases in costs, lower productivity, and increase in government employment. The model suggests that only an increase in money supply can produce a long-term and continuing inflation. Of the four, business-cycle changes in price receive the most political attention, but appear to be the least important. Identifying the different influences on prices should help in the analysis of inflation.

The long wave, often called the Kondratieff cycle, refers to the rise and fall of economic activity over some 45 to 60 years. The long wave is associated with the Great Depressions of the 1830s, 1890s, and 1930s. The National Model generates such behavior and provides a theory for periodic repetition of such economic difficulties.

An energy sector for the National Model has been developed and tested. When added to the model it will become a vehicle for testing alternative energy policies.

Research is now being revived in the application of system dynamics to corporate policy. During the last year, policy models have been developed in cooperation with several corporations.

The National Model program is supported by contributions from some 30 sponsors representing corporations, foundations, and private individuals.

Management of Technological Innovation

Teaching and expanded research in this area continued to focus on the problems of generating effective technological innovation. The efforts fall into 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, Professors Thomas J. Allen and Ralph Katz are continuing their work on the performance of long duration R&D project groups with funding from the Department of Defense. The essential question of this research concerns how R&D groups and projects maintain their effectiveness over extended periods of time. In investigating this issue, Professors Allen and Katz are focusing on several important aspects of R&D groups as a function of group age: motivation of scientists and engineers, supervisory behaviors and skills, various kinds of communication patterns, degrees of group heterogeneity along a number of dimensions, perceptions of job and task characteristics, and the reactions of R&D professionals to their work environment. Particular attention is being given to the overall structure of the laboratories (i.e., matrix, project-oriented, or functionally oriented) and to the career and project movements of R&D staff members. Data have already been collected from over 2,000 R&D professionals in more than 50 projects, and information-gathering will continue through summer 1980.

Professor Katz also has been collaborating with Professor Michael Tushman of Columbia University on a study of communication effects on R&D performance. The importance of gatekeepers hypothesized by Professor Allen has been demonstrated in this research which is now summarized in several recent working papers.

Also in the area of R&D staffing Professor Roberts has continued his work on the development and applications of the "critical functions" analysis of innovation-focused organizations. The description of this approach to assessment of several government laboratories, coauthored with Richard Rhoades and Alan Fusfeld, received second prize in the "Best Paper of the Year Awards" by *R&D Management*. Roberts and Fusfeld have recently issued a revised working paper on the critical functions approach.

In the area of structure, Professor Eric A. von Hippel has continued to focus on the relationships between users and manufacturers of innovative industrial goods, under recently renewed NSF funding. 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 semiconductor and electronic subassembly production equipment. While expanding his studies into several other industries, Professor von Hippel also has been developing a theoretical framework for linking the locus of an innovation with the appropriability of its benefits. He also has been studying with Professor Stan N. Finkelstein the linkages between users and innovators in the area of automated clinical laboratory technology; they have published a comparative analysis of the duPont and Technicon experiences.

Professor Allen has continued his studies of technical communication on an international level with his research in the Republic of Ireland. That study has now focused on the mobility of technical personnel. Extension of these studies to Spain occurred during the past year.

In regard to strategy, Professor Roberts continued his interests in corporate new venture organizations and in the formation of new enterprises, and has published a new paper on this subject in the *Harvard Business Review*. Professor Finkelstein, with support from the Whitaker Health Sciences Fund, has been looking at the determinants of academic medical innovations and their utilization. Professors Roberts and Finkelstein collaborated in planning a major conference on

biomedical innovation sponsored by the National Institutes of Health, and co-chaired by Professor Roberts. Professor Roberts has been 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.

A collaborative study was concluded during the year involving Professors Roberts and Hollomon and Professor James Utterback of the School of Engineering's Center for Policy Alternatives. The study examines the incentives provided by the State of Israel to encourage industrial product innovation. A comparable research program, involving the same group with the addition of Professor Allen, has recently been undertaken in Sweden. Professor Roberts also has initiated activities to update his 1960s data on new enterprise formation and growth in the Greater Boston area.

A major effort continued on the faculty study co-chaired by Professors Roberts and Hollomon to design a new joint Engineering-Sloan School Master of Science Program on the Management of Technology. The committee proposal has now received tentative approval by the Committee on Graduate School Policy, as well as initial industrial sponsorship funds from Pilkington Ltd. to support the curriculum development efforts needed.

Corporate Strategy, Policy and Planning

During the year there was a continuation of curriculum development efforts in this area. A series of new subjects is now formally offered, some of which have been tried on an informal basis during the last several years. Another new subject developed this year will be offered jointly by the Sloan School and Ocean Engineering, and used by the Center for Transportation Studies. Professor Zannetos who carried these efforts in the past was joined by Professor Bowman this year.

Another activity associated with curriculum development has been the establishment of concentration options in policy and strategy for our Master's programs.

Professor Louis Banks continues his work in the area of business and the media. His analysis points out the consequences of living in a "newsocracy."

Professor William Bottiglia is completing a major piece of intellectual work dealing with the philosophy of civilization. This is the culmination of many years of research.

Professor Bowman continues his empirical investigations in the relationship between risk and return. Among other issues he attempts to ascertain the consistency between theory and practice.

Professor Zannetos is involved in a variety of research projects. He has continued (with Professor Porter of Harvard University) to analyze the impact of administrative regulation as contrasted to market regulation. The work started many years ago on oil economics, and oil transportation by ocean tankers also continues. Professor Zannetos has, in addition, maintained his interests in a variety of other aspects of organization and industry structure.

International Management

Professor Richard D. Robinson began a major study of entry strategies used by American firms to gain access to the market of the People's Republic of China. A preliminary investigation was completed this year involving interviews in 120 corporations by 12 students in the context of a structured Master's thesis at Sloan. Professor Robinson also continued research on the PRC's foreign investment law and the response of both foreign firms and the regulatory authorities. The investigation will be pursued during a trip to China in July.

Professor Lessard's research on financial mechanisms for shifting commodity price risks and on foreign exchange risk management and capital budgeting were noted earlier.

Professor Lessard's new line of comparative research on public enterprise finance in LDCs (conducted with colleagues at the Harvard Institute of International Development) promises to provide useful guideposts for the strategic and operating decisions of LDCs in their consideration of appropriate public enterprise policy.

Professor Stephen J. Kobrin has continued his investigation of the assessment and evaluation of international social and political environments by US-based firms. A large-scale field study, involving both a mailed survey and a large number of follow-up interviews, was completed. Professor Kobrin is currently completing a book based upon the study which views the assessment of non-market environments in the general context of organization-environment interaction.

Professor Kobrin also has continued to work on his analysis of the forced divestment of foreign-owned firms in the developing countries. A study of the political-economic determinants of expropriation was completed, and an investigation of the effect of expropriation on future flows of investment was begun.

Professor Nyhart's primary research in the international management area during 1979-80 was the continuation of work on the MIT Deep Ocean Mining Modeling project of which he is the principal investigator. The research, sponsored by the Division of Marine Minerals of the Department of Commerce's National Oceanographic and Atmospheric Administration (NOAA), the Department of State, and the Treasury Department, concentrated this year on a thorough revision of the model's structure and central values, an effort which will continue into the next academic year. In this work, project members are collaborating with three nationally recognized private sector persons under contract to the NOAA for this purpose and with NOAA personnel.

Other aspects focused on modeling likely tax treatments for deep ocean mining under the tax structures of the United Kingdom, France, the Netherlands, Germany, Japan, and Singapore. The model was used during the year as the basic analytic tool underlying the successful negotiations of the financial arrangements provisions of the Third United Nations Conference on the Law of the Sea draft treaty.

Work began on a second modeling project, Oil Spill Equity and Regulatory project. The aim of this project is to model the United States' oil spill clean-up system. Though its immediate internal link is peripheral, the model eventually should be useful in other countries' oil pollution management efforts.

Finally, some research was undertaken to gain access to materials relating to international harmonization efforts in several transnational areas of regulation -- non-tariff trade barriers, antitrust policy, toxic substances, trans-border electronic data transmission, and corrupt practices.

Health Care Management

The Sloan School continued its program in health care management teaching and research, and continued efforts to expand resources in this programmatic area by active collaboration with other MIT departments. With the Association of American Medical Colleges, the Sloan School has developed and presented multi-phase management education programs for the medical schools of the US and Canada. Professors Beckhard and Roberts, representing the applied behavioral sciences and the planning and management sciences, respectively, exercised joint responsibility for design and leadership of these activities, with active involvement of Dr. Rockart, and numerous faculty recruited from other universities. Over the past several years Phase I of these programs has involved nearly every dean of the 130 North American medical schools in a one-week management program. About 80 medical schools have already participated in the follow-up Phase II teams 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 MIT/AAMC program are scheduled for the coming year, under the continuing sponsorship of the Robert Wood Johnson Foundation. Additional Phase I-type programs have now been developed and are being presented on a continuing basis to directors of teaching hospitals and to chairmen of academic departments of medicine. In a related activity with the AAMC, Dr. Rockart conducted an educational effort in financial management for academic medical centers. Sloan School faculty also have been involved in presenting similar management education efforts to deans of pharmacy schools and chairmen of surgery, radiology, and pathology departments. As part of this program, Professor Roberts has developed a videotaped series of lectures under funding from the National Library of Medicine of the National Institutes of Health.

During the year Dr. Rockart advanced his research on the possible role of distributed information processing systems to aid patient management in hospitals, and on methodologies for designing

hospital information systems. Dr. Rockart completed his studies that had been funded by the Veterans Administration, testing a method for information system structuring at the Boston VA Hospital. With Professor Roberts, Dr. Rockart is working with Alan Dowling, a Ph.D. candidate in the Sloan School, in studying the acceptability and utilization of computer systems in community hospitals. Mr. Dowling has published initial findings showing high incidence of staff interference in the implementation of medical information systems.

Efforts continued in the transfer of research approaches, developed earlier in the area of management of technology, to problems of health care technology. Professor von Hippel collaborated with Professor Finkelstein, M.D., to examine factors affecting the development and commercialization of health innovations, and they have authored an initial working paper on the effect of government regulations. Professor Finkelstein continued his research on the clinician role in the generation and utilization of medical innovations, supported by funds from the Whitaker Health Sciences Fund. Professor Finkelstein's research on health technology is supported broadly by funds from the National Heart, Lung, and Blood Institute of the National Institutes of Health (NIH). Working with Dr. Edward Sondik of the NIH, a recent appointee as research affiliate in the Sloan School, Dr. Finkelstein has undertaken research on the effectiveness of clinical trials as a means of evaluating emerging health technology. Both are also examining the adoption and social impact of new health-care technology, partially funded by the Health Care Financing Administration of HEW. Professor Finkelstein is also working on the development of mathematical models for cost and social impact analysis of selected health technologies and practices.

Professors Roberts and Finkelstein worked closely during the year with the National Heart, Lung, and Blood Institute to develop and conduct a state-of-the-art conference on the development and dissemination of biomedical advances. This conference, co-chaired by Dr. Roberts, has resulted in a book manuscript, "Biomedical Innovations," co-edited by Professors Roberts and Finkelstein and NIH collaborators, that has been accepted for publication by the MIT Press.

Professor Norman S. Stearns, Associate Dean of the Tufts School of Medicine, continued his collaborative efforts as Visiting Professor of Health Management at the Sloan School. In addition to his teaching and thesis support endeavors, Dr. Stearns developed a research proposal relating to determinants of the quality of care.

The health policy and management programs at MIT are included in the Institute-wide formation of the Whitaker College of Health Sciences, Technology, and Management, with Professor Roberts chairing its health policy and management area. A new joint biomedicine-management Ph.D. program was designed during the past year as part of this new Whitaker activity, and a broad research program is being planned with special emphasis on policy and management relating to health technology. Funding efforts are actively under way to launch these programs in the near future.

The Health Management Executive Development Program experienced its fifth year of successful operation in association with the Sloan Fellows Program, with its largest class to date. As part of this program Professor Stearns continued his leadership of a year-long Seminar in Health Management, co-taught with Professor Roberts. This seminar, which will continue next year, brought to the Sloan School 25 leaders of medical schools and hospitals, government health agencies, and health-related corporations for comparative assessments of management style and effectiveness. A new group of Health Management Executives has been admitted for the 1980-81 program year and efforts are now under way to more routinely integrate this health management option as an ongoing part of the Sloan Fellows Program.

Two academic visitors contributed importantly to new program idea development, while working with faculty and graduate students. Barbara McNeil, M.D., of the Harvard Medical School, participated during the fall semester as Visiting Associate Professor of Health Management, and contributed to efforts in developing research in health technology. Stanley Troup, M.D., senior vice president of the University of Cincinnati, director of its Medical Center, and an alumnus of the Sloan Fellows Program, served as Visiting Professor of Health Management in the spring semester, participating in the health management seminars of Professors Beckhard, Roberts, and Stearns, and carrying out activities in the area of medical center strategic planning.

EXTERNAL RELATIONS

An administrative area was created last year to give focus to the School's overlapping activities with external constituencies (alumni, corporations, and the media): to help members of those groups relate more effectively with the School and to provide a basis for fund-raising efforts. Associate Dean Gil assumed responsibility for this area and during the first year concentrated his efforts on particular fund-raising projects and general fund-raising with alumni.

This year an increase in staff has provided necessary support to make further progress in this area. Pamela W. Turner, director of External Relations, is working on corporate and media relations; and B. Leigh Chapman, manager of External Relations, on alumni relations. Mrs. Turner served formerly as director of placement and manager, Accelerated Master's Program. Ms. Chapman is a graduate of the Sloan School and prior to joining the staff was manager of business planning in Europe for Hertz Corporation.

In all of the School's external relations an effort has been made to coordinate the School's activities with those of other areas of the Institute, such as the Development Office, the Alumni Association, and the News Office.

In coordination with the Development Office and the Industrial Liaison Office, a corporate sponsorship activity was created. Sponsorship provides a mechanism for acknowledging the School's existing corporate relations as well as soliciting unrestricted support for research and curriculum development from organizations which historically have not participated in the Industrial Liaison Program. The sponsorship mechanism was formally launched in the last quarter of this fiscal year. Invitations have been extended to organizations which have not previously supported the School. In addition, permission has been requested from existing corporate donors to list them as sponsors.

The staff, also in conjunction with the Development Office, prepared a major fund-raising proposal which was submitted to the Glenmede Trust in March and resulted in a contribution of \$3 million seed funding for the facilities renovation.

A list of potential donors (corporations and foundations) has been developed for review by the Development Office. A proposal has been prepared and sent to CONOCO for a faculty career development chair and another major proposal is being prepared for the Sloan Foundation.

Funding for the Sloan Fellows Chair has been increased from about \$325,000 to about \$730,000 this fiscal year; and the Schell Chair funding, accomplished primarily in this year, has reached a level of approximately \$500,000.

Alumni have responded to increased communication about the School, and alumni giving to the School and the Institute as of May 1 was almost \$500,000 (including pledges), compared to a fiscal year 1978-79 total of about \$165,000 -- an increase of 300 percent.

Other alumni activities this year have included establishing a first regional alumni group. In New York City a senior advisory board of alumni will provide counsel to a committee of younger alumni in organizing activities for management alumni in the area. Dean Gil and Ms. Chapman have met with each of these groups.

In the area of media relations, lines of communication with journalists of leading business publications are being developed in coordination with the MIT News Office. Some results from this ongoing effort are already visible. For example, in a May 1980 issue of *The New York Times* the MIT management school was for the first time included in a story on leading US business schools.

FACULTY

During the past year Professor Robert C. Merton was named the J. C. Penney Professor of Management. Professor Merton has been on the Sloan faculty since 1969 and works in the field of finance and monetary theory.

Four faculty members were promoted to the rank of full professor. They are Professors Magnanti, Pindyck, Schmalensee, and Welsch.

Dr. Bowman returned to the corporate policy and strategy area of the Sloan School as a full professor. Since leaving the Sloan School in 1974 until his return, Professor Bowman was dean of the College of Administrative Sciences at Ohio State University.

Professors David K. Hsiao, Rosabeth M. Kanter, and Professor McKersie joined the Sloan School as visiting professors. Professor Hsiao, whose field is management information systems, is associated with Ohio State University. Professor McKersie, a scholar in the employment and labor-management relations area, is dean and professor at the School of Industrial and Labor Relations at Cornell University; and Professor Kanter, whose field is organizational studies, is associated with Yale University.

Professors Barocci, Kobrin, Meldman, and Professor Nathaniel J. Mass were promoted to the rank of associate professor.

Drs. Bagozzi and Keen were appointed to the faculty as associate professors. Professor Bagozzi, whose field is marketing, received his Ph.D. from Northwestern University and was assistant professor at the University of California at Berkeley. Professor Keen, who was formerly on the Sloan School faculty as an assistant professor in the management information systems area, has been on the faculty at Stanford University.

Drs. Brownell, Orlin, Stoker, Wong, and Dr. John W. Morecroft were appointed to the rank of assistant professor. Professor Brownell received his Ph.D. from the University of California at Berkeley and joins the Accounting and Control Group; Professor Morecroft, a former doctoral student in the System Dynamics Group, received his Ph.D. in 1979 and has joined that group. Professor Stoker, who has a Ph.D. in Economics from Harvard University, is a member of the Economics Group. Professor Orlin, whose degree is in operations research from Stanford University, and Professor Wong, a statistician whose Ph.D. is from Yale University, both joined the Operations Research Group.

Professor Paul R. Krugman, who received a Ph.D. in Economics from MIT and is associated with Yale University, was a visiting assistant professor in the Economics Group.

Dr. Markus, a Ph.D. candidate at Case Western Reserve University, joined the Management Information Systems Group as a postdoctoral fellow.

Joseph Vittek, who holds an LL.M. degree from Harvard University, was appointed a lecturer in the management information systems area. David Sherman, a doctoral candidate at Harvard Business School, was a lecturer in the accounting area.

There were three additions to the Sloan School administrative staff. Jeffrey A. Barks is director of the Master's Programs. He is a graduate of the Wharton School at the University of Pennsylvania, and was formerly associated with Dartmouth College. H. Scott Duncan joined the Executive Development Programs as associate director. He was formerly with the Peace Corps. Ms. Chapman, a Sloan School graduate, came from the Hertz Corporation to become manager of External Relations.

Two administrative staff members were promoted. James T. Gabbert, Jr., who has worked in the Ph.D. Program Office, was promoted to coordinator of the Ph.D. Program. Paula B. Cronin, formerly associate director of Placement, was promoted to director of Placement.

Walter H. A. Vandaele joined the Sponsored Research Staff as a senior research associate with the Center for Computational Research in Economics and Management Science. Dr. Vandaele holds a Ph.D. from the University of Chicago, and was formerly associated with Harvard University.

Three employees in the sponsored research centers received promotions to staff positions. Sarah S. Fitzgerald was promoted to staff of the Center for Information Systems Research, Kathaleen A. Rankin was promoted to staff of the Center for Computational Research in Economics and Management Science, and Dorothy Speidel was promoted to staff in the Systems Dynamics Group.

Several visiting scholars and one visiting scientist spent time at the Sloan School this past year. Giovanni Andreatta, from the University of Padova, Italy, is an expert on energy policy. Barbara J. McNeil, a physician who specializes in nuclear medicine and is affiliated with Peter Bent Brigham Hospital, worked in the health management area. Kazuhiko Nishina, a Fulbright Scholar from Japan, worked in the finance area. Rosemary Stewart, who holds a Ph.D. from the London School of Business and is a fellow at the Oxford Center for Management Studies, joined the Organizational Studies Group. Finally, Svein Strommen, from the South Dakota School of Mines and Technology, joined the Management Information Systems Group.

Four faculty members were on sabbatical leave this year. Professor Donovan was on leave from the Management Information Systems Group. Professor Shapiro was on full-time leave, and Professor Welsch was on half-time leave from the Operations Research Group, and Professor Urban was on leave from the Marketing Group.

Four additional faculty members took a leave of absence during the 1979-80 academic year. They were Professor Thurow from the Economics Group; Professor Lessard, on leave during the fall term from the Finance Group; Professor Lorange, on leave from the Planning and Control Group; and Professor Michael D. Zisman from the Management Information Systems Group.

We record with regret several departures from the Sloan School at the end of the 1979-80 academic year. Professor Lorange and Professor Alloway left the Accounting and Control Group. Professor Kalwani departed from the Marketing Group, and Professor Zisman left the Management Information Systems Group.

We were deeply saddened by the untimely death of our former student and colleague, Gilbert W. Low. Professor Low joined the Morgan Guaranty Trust after receiving his Ph.D. from MIT and became vice president there. He returned to the Sloan School in 1977 to work with Professor Jay W. Forrester and the Systems Dynamics Group. His accidental death while vacationing in the summer of 1979 is a loss felt by us all.

One faculty member retired this year. Stanley M. Jacks, senior lecturer on the Sloan School faculty, retired from the manpower and labor relations area. Mr. Jacks is an expert on industrial relations and labor law and was first appointed to a faculty post in 1946. He has been a member of the Sloan School faculty since 1959, teaching subjects on American legal systems and labor law. His valued contributions to the School will be greatly missed.

WILLIAM F. POUNDS

It is with very mixed feelings that we report the resignation of William F. Pounds as Dean of the Sloan School. Dean Pounds was first appointed to the Sloan School in 1961 as assistant professor. He became associate professor three years later, and in 1966, became Dean and professor. He has ably led the Sloan School for the past 14 years, bringing to the School faculty of exceptional strength both in teaching and research. Under his direction new programs grew and existing ones flourished. We are heartened to know that Dean Pounds will, after a leave of absence, continue his association as Professor of Management.

ABRAHAM J. SIEGEL

School of Science

Progress in science continues to change our views of the physical and biological worlds and to open up new ways of doing things, and even new things to do. Recombinant DNA techniques hold the promise of the more economical production of certain pharmaceutical products and the creation of products not currently available. The development of new understanding of catalysis is leading to new processes for the chemical industry. New ideas in seismology promise to improve methods of exploring for oil and other natural resources. The development of mathematical statistics is leading to better analysis of high dimensional data. Recent research on the mechanisms of action of toxic chemicals is assisting in the development of priorities so that preventive work can be done in the most serious environmental problems. The global carbon dioxide problem is being studied because of its potential effect on long-term climate. The recent discovery of particles and the development of quantum chromodynamics are rapidly changing fundamental physics, as is progress in supergravity theory. The recent developments in solid state physics and plasma physics are contributing to the development of very large scale integrated circuits and thermonuclear power research, respectively.

Employment opportunities for graduates of the School of Science were better this year, and, in most areas, are probably better than they have been for a decade. In fact, this year there are growing problems of shortages of new doctoral scientists in certain fields of science. Part of the reason for increasing shortages is the fact that US doctorate production has been decreasing in various fields of science during the decade of the 1970s. During the 1970s the annual doctorate production in the United States has declined 30 percent in chemistry, 33 percent in physics and astronomy, and 37 percent in mathematics. The annual doctorate production in the biological sciences has remained approximately constant during the 1970s. By the end of the 1980s the retirement rates for doctoral scientists will be considerably greater than current retirement rates, and so this will increase the needs for young doctorates. The development of new national problems in synthetic fuels, solar energy, toxicology, and very large scale integrated circuits can be expected to cause further shortages. If the people of the country want to have our own energy resources more fully developed, medical care improved, computers more widely used, the environment protected, and the US continue its strong leadership role in providing a high standard of living and leadership in science and technology, then more doctorate scientists are going to be required. Progress in all of these important areas requires more than doctorate scientists, but they are emphasized here because the successful coping with these societal problems is going to require increased levels of research and development.

If the problems facing the country could be easily solved, the United States could take a more relaxed view; but these are difficult problems which are going to require increasing dedication of both human and capital resources. It is not just a question of finding technical solutions to these problems, but of solving them within constraints. For example, there is a desire for better medical care; but in providing better medical care for all groups, it is essential to contain costs so that this sector does not increase rapidly as a percentage of the total economy.

ACADEMIC PROGRAMS

The number of undergraduates in the School of Science this year was 797, compared with 897 last year. Thus, the decline of the last several years has continued, and the number of engineering majors has increased a corresponding amount. Although the number of science majors has declined, the teaching load in the School of Science has not decreased as much because engineering students continue to study science and mathematics in their upperclass years. In the two terms of fiscal year 1979 the School of Science taught 239,221 credit units, and this year the corresponding figure was 233,337, a drop of 2 percent.

In order to provide the freshmen with an added opportunity to learn about the undergraduate programs in the School of Science and to describe career options, the School presented a program to communicate information about the eight undergraduate courses offered by the School and about future career possibilities for scientists.

The Committee on Educational Policy transferred its responsibility for the Experimental Studies Group to the School of Science, and determined that this program is now a regular educational program. This special freshman program, headed by Professor Robert Halfman, will have a faculty advisory committee, chaired by the Dean of Science. This program has been in operation for 11 years, and 469 freshmen have participated in it. The program provides students with an opportunity to choose alternate ways to study the material required and provides a supportive learning community.

The enrollment of regular graduate students in the School of Science was essentially the same as it has been the preceding two years -- 1,061, as compared with 1,063 in both September 1977, and September 1978.

At its meeting of June 2, 1980, the Corporation acted formally on the recommendation to change the name of the Department of Meteorology to Department of Meteorology and Physical Oceanography. The circulation of the atmosphere is tied to the circulation of the oceans and the basic mathematical description of the two fluids is the same. As part of the organizational change, Professor Carl Wunsch, Cecil and Ida Green Professor of Physical Oceanography, and Professor Charles Erickson will have joint appointments in the Department of Earth and Planetary Sciences and the Department of Meteorology and Physical Oceanography.

The faculty members teaching the freshman science requirement subjects met six times during the year. This Core Group was augmented this year by Dean Harry Hanham and several others interested in the Core of the undergraduate educational program. During the year, the report of the New England Association of Schools and Colleges on accreditation re-evaluation of MIT was received and discussed by the Committee on Educational Policy. A subcommittee chaired by Professor Michael Driscoll (Nuclear Engineering) discussed focal points for a review of the freshman year. The Core Group discussed a number of these issues with Professor Driscoll and others.

The summer course "Principles of Toxicology," which was offered for the first time last summer, is being offered again in the summer of 1980 with the assistance of a training grant from the Environmental Protection Agency (EPA). The training grant provides stipends and tuition for 24 trainees. In addition, the EPA will send about 10 of its employees to take the course. This course has been developed to assist in the education of scientists and engineers who can contribute to the solution of problems arising from the use and disposal of toxic chemicals. There is a serious shortage of people who have the background required by the new positions in industry, government, and universities which have been created to work on these problems. This special summer program has been developed by a faculty committee, chaired by the Dean of Science. Professor Gerald N. Wogan is responsible for the academic program, and academic credit (30 units) is provided through the Department of Nutrition and Food Science. Harvard faculty members and industrial scientists are involved in planning and presenting the course.

RESEARCH

The fiscal year 1980 research volume of the School of Science was estimated this spring to be \$31,725,000, compared with \$27,761,000 for fiscal year 1979; this is a 14 percent increase. These totals do not include the interdepartmental laboratories which involve faculty members from the School. Estimates of the total research volume of the School of Science, including fractions of the interdepartmental laboratories that correspond with the participation of faculty members from the School, yield annual expenditures about double the above figures.

The Spectroscopy Laboratory received a \$1.5 million grant from the National Science Foundation to establish a regional center for advanced laser systems. The center will be known as the Northeast Regional Center for Laser Spectroscopy and Dynamics. Professor Michael S. Feld will

serve as director and Professor Jeffrey I. Steinfeld will serve as associate director of this regional center.

The Institute Safety Council met about every two months during the year. They discussed possible actions to increase the safety of laboratory work at the Institute and have interacted with department heads and laboratory directors about these activities. This year, more has been done by the departments and laboratories to provide safety instruction to incoming graduate students, postdocs, and technical assistants. The disposal of low-level radioactive wastes and chemical wastes has received increased attention this year. For a two-month period in the fall, the three low-level waste burial sites approved by the Nuclear Regulatory Commission were all closed to liquid wastes. Fortunately, the site at Richland, Washington, reopened so that a crisis was avoided, but this is a long way to ship low-level liquid wastes.

FACULTY

Professor Christopher T. Walsh, Professor of Chemistry and Biology, was appointed Associate Director of the Whitaker College of Health Sciences, Technology, and Management.

Professor B. Clark Burchfiel served as Acting Head of the Department of Earth and Planetary Sciences for the period March 1 to June 30 while Professor Wunsch took a brief sabbatical at Harvard University.

It is not possible to record all of the awards bestowed on faculty members in the School of Science this year, but several honors are especially noteworthy. Professor Victor F. Weisskopf received a 1979 Medal of Science, the Nation's highest award for scientific achievement. Earlier medalists from the School of Science were Norbert Wiener (1963) and Claude Shannon (1966).

Professors Herman Chernoff and George Clark were elected members of the National Academy of Sciences. Professor Karl U. Ingard was elected to the National Academy of Engineering. Professor Jerome I. Friedman was elected to the American Academy of Arts and Sciences.

Professor Alexander Rich, Sedgwick Professor of Biology, has been selected as the recipient of the 1980-81 James R. Killian, Jr., Faculty Achievement Award. Recently his laboratory announced a new double helical form of genetic material which is left handed, in contrast with the usual Watson-Crick form of DNA.

Several faculty members received named professorships this year: Professor John Deutch returned from a leave to serve in the Department of Energy and was appointed Arthur Clay Cope Professor of Chemistry. He served successively as Director of Energy Research, Acting Assistant Secretary for Energy Technology, and Undersecretary of the Department of Energy.

Professor Daniel G. Quillen was appointed Norbert Wiener Professor of Mathematics. This professorship was held previously by Professor Isadore Singer. Professor Quillen received the Fields Medal at the meeting of the International Congress of Mathematicians in Helsinki, Finland, in 1978.

Professor Irwin Shapiro (Department of Earth and Planetary Sciences and the Department of Physics) was appointed Schlumberger Professor of Geophysics and Physics. He is the first holder of this chair which is a gift from the Schlumberger Foundation.

Professor George M. Whitesides was appointed the Robert T. Haslam-Bradley Dewey Professor of Chemistry. He is the first holder of the chair. This is a new professorship which is a gift from the Grace Foundation.

Professor Wogan was appointed the Underwood-Prescott Professor of Nutrition and Food Science. The first holder of this chair was Professor Samuel A. Goldblith, who is now Vice President for Resource Development.

During this year the departments in the School of Science appointed several new professors from other universities: Professor William H. Orme-Johnson moved from the University of Wisconsin to the MIT Chemistry Department. Professor Daniel Freedman moved from the State University of New York at Stony Brook to the MIT Mathematics Department. Professor Susumu Tonegawa will move to the MIT Biology Department and Center for Cancer Research from the Basel Institute for Immunology in Switzerland in June 1981. Professor Barry Sharpless of Stanford University was appointed Professor of Chemistry. He had been a member of the MIT faculty earlier, and we are happy that he is back. Dr. John V. Evans, an Assistant Director of Lincoln Laboratory, was appointed Professor of Meteorology and Director of the Haystack Observatory.

Professor Hamish N. Munro became Director of the new Center for Human Nutrition operated in Boston by the United States Department of Agriculture. He will continue teaching at MIT as Adjunct Professor of Physiological Chemistry.

Professor John Ross of the Chemistry Department resigned to go to Stanford University. He had come to MIT in 1966 as Head of the Department of Chemistry, and served in that capacity until 1971 when he returned to research and teaching as the Frederick G. Keyes Professor of Chemistry.

Professor Howard Green is moving to Harvard Medical School to become Head of the Department of Physiology.

Dr. George R. Harrison died on July 27, 1979. He was Professor of Physics, Emeritus, and Dean of Science, Emeritus. George Harrison was the second Dean of Science at MIT and served in the period 1942 to 1964. He had come to MIT from Stanford in 1930 as a part of President Karl Taylor Compton's program to strengthen the science departments. He founded the MIT Spectroscopy Laboratory and, in addition to carrying out various types of spectroscopic research, advanced the techniques of ruling diffraction gratings to make the largest and most perfect gratings available.

ROBERT A. ALBERTY

Experimental Study Group

The academic year 1979-80 marked the beginning of the second decade for the Experimental Study Group (ESG). Although it has evolved over the years, it continues to be a small, individualized learning community for freshmen and sophomores who are interested in a self-directed study program.

By vote of the Committee on Educational Policy in the fall of 1979, ESG is no longer considered an educational experiment, but will be offered to MIT undergraduates as "a regular program of the Institute under the auspices of the School of Science." Overall educational responsibility is now vested in a Faculty Oversight Committee chaired by Robert Alberty, Dean of Science, with members drawn from the departments of Chemistry (Professor Alan Davison), Physics (Professor Anthony French), Mathematics (Professor Arthur Mattuck), and the School of Humanities and Social Science (Professor Jean Jackson), with Professor Robert Halfman, Chairman of ESG, as an ex officio member.

The sense of continuity engendered by these changes has stimulated the members of ESG to play for the future with imagination and confidence, especially in the use of and staff support for undergraduate tutors, in the expansion of the variety of subjects available for credit in ESG, in the increased recruitment of part-time professional staff, and in the rearrangement and refurbishing of the physical facilities.

Experimental Study Group

In 11 years of operation, 469 freshmen have participated in ESG under the guidance of 93 professional staff, ranging from teaching assistants to emeritus professors. In the current academic year, 39 freshmen joined ESG for the fall term and 45 joined in the spring term, bringing the total number of freshmen enrolled in one or more terms of ESG to 56, the highest number in ESG's history. They were taught by 11 staff members and 20 upperclass tutors (all of whom were in ESG as freshmen). Although the staff at ESG varies from year to year depending on the availability of staff from MIT departments, several members of the MIT faculty have provided a sense of continuity to ESG staffing through their long-term involvement with ESG -- Professor Emeritus Ned Frank and Professor Michel Børanger in Physics, Professor Clark Stephenson in Chemistry, and Professor Ken Manning in Humanities and Social Science. Professor Halfman has handled the administrative affairs of ESG as chairman for the past six years, aided by Holly Sweet as assistant to the director, now in her third year at ESG.

As upperclassmen, the students from ESG have moved into regular undergraduate degree programs with about the same distribution as their classmates and with the same grade point averages in their upper years. An interesting and distinguishing characteristic is their greater willingness to assess their own educational needs and act on their conclusions. Thus a higher percentage of ESG students take time away from MIT, transfer to a more suitable school, graduate quite early or quite late, or pursue unconventional degree programs. Another characteristic is their interest in remaining involved in ESG as upperclassmen -- to tutor freshmen, to advise newcomers, or to participate in a variety of ESG activities. In some ways the real continuity of ESG occurs through the commitment of its upperclassmen.

Information from several surveys distributed to ESG students and alumni between 1978 and 1980 has shown that the great majority of students (85 percent) responding to the surveys were in favor of their experience in ESG and would have repeated the decision to join if given the chance. They joined ESG for two main reasons: to participate in self-paced, independent study, and to find an alternative to the regular curriculum which they felt was not meeting their educational needs. The primary benefits that they felt they gained from being in ESG were somewhat different: personal benefits (such as self-growth, increased self-confidence, and extra personal attention), high quality of education (better understanding of the material, superior instruction), close staff-student relationships, and participation in a closely-knit academic community. The continuing effectiveness of the ESG program in serving the diverse and changing needs of its students and staff over the past 11 years appears to rest on its emphasis on the individual, on meeting his or her needs through a flexible approach and personal attention, in a setting which encourages interaction and experimentation.

R.L. HALFMAN
HOLLY SWEET

Department of Biology

In the past year, 259 undergraduates were listed as Life Sciences majors and 106 received the Bachelor of Science in Life Sciences. Most of these graduates will be attending either medical school or graduate school. There were 112 Ph.D. candidates registered in the Department and an additional 17 in the Joint Program in Biological Oceanography with Woods Hole Oceanographic Institution. Between July 1, 1979, and June 30, 1980, 15 Ph.D.s and one S.M. were awarded in the Department, and four Ph.D.s and one S.M. in the Joint Program. The entering graduate class in 1979 was 24 and the entering class in September 1980, will be 33 -- plus five new students in the Joint Program in Biological Oceanography.

EDUCATIONAL ACTIVITIES

No significant changes in the undergraduate curriculum have been made in the past year. The basic subjects that all students take are: Genetics, General Biochemistry, and Introduction to Experimental Biology. Most students also take General Biology. These subjects are pre-requisites for the upper-level subjects that students take to complete their program in the Life Sciences.

All of the regular (Course 7) Life Sciences majors are required to acquire experience in laboratory research. This can be satisfied by taking one of the four research-oriented project laboratories offered by the Department, or by completing the equivalent amount of research work in a research laboratory. Those students who do not want to be involved in laboratory research can enroll in the alternate 7A program which does not require laboratory research. Approximately 15 percent of the Life Sciences majors graduate in the 7A program.

The recipients of the annual John L. Asinari Awards for the 1979-80 year for outstanding research by undergraduates in the Life Sciences were Myung Gi Choi, David Frank, and Joseph Vierra, all of whom were seniors.

The Department graduate program requires that graduate students must demonstrate expertise in the following areas: genetics, general biochemistry, cell biology, and molecular biology. This can be satisfied by passing placement examinations in these subjects upon entering the graduate program, or by taking the relevant subjects offered by the Department in these areas. Graduate students are trained in the following disciplines: biochemistry, cell and developmental biology, microbiology, biophysics, virology, genetics, immunology, and neurophysiology.

RESEARCH

The research activities in the Department are concentrated in the area of molecular biology. Individual research projects are described in the annual departmental publication, *Biology Research Summaries*. The current edition is available at departmental headquarters.

Departmental personnel engaged in research activities include: 43 faculty members, five visiting faculty and scientists, 110 postdoctoral associates and postdoctoral fellows, 48 technical assistants, 26 hourly employees, 23 biweekly employees, 110 graduate students, and approximately 70 undergraduate students.

The departmental Electron Microscope Facility is being expanded with the arrival of a new scanning electron microscope in June 1980. The facility will then consist of four microscopes which can be used both for research and teaching. Professor Jonathan King is the director of this facility and, for the past year, Erika Hartweg has been the associate director.

The Protein Chemistry Laboratory has now been operating for a year as a departmental facility under the supervision of Professor Robert Sauer. This relatively new laboratory has been an unqualified success in that it is in constant use by various members of the Department. We are very grateful to the General Mills Foundation and the Athwin Foundation for grants which allowed the establishment of this useful facility.

FACULTY

The Department made three new faculty appointments in the past year. Dr. Susumu Tonegawa was appointed as professor, with research laboratories in the Center for Cancer Research. His appointment will become effective in June 1981. Dr. Tonegawa received the B.S. in chemistry from Kyoto University and the Ph.D. in biology from the University of California at San Diego. For the past nine years he has been a member of the Basel Institute for Immunology in Basel, Switzerland.

Department of Biology

Dr. Thereza Imanishi-Kari has been appointed assistant professor, effective December 1980, with research laboratories in the Center for Cancer Research. Dr. Imanishi-Kari received the B.S. in biology from the University of Sao Paulo, the M.S. from Kyoto University, and the Ph.D. in immunology from the University of Helsinki, Finland. For the past five years she has held a research appointment at the University of Cologne, West Germany.

Dr. Barbara Meyer has been appointed as assistant professor. She will arrive in December 1981. Dr. Meyer received the B.A. in biology from Stanford University, the M.A. in molecular biology from the University of California at Berkeley, and the Ph.D. in biochemistry and molecular biology from Harvard University. Since 1979 she has been a postdoctoral trainee at the Medical Research Council, Cambridge, England.

Professors Mary Lou Pardue and Lisa Steiner were promoted to full professor. Professors Richard Hynes and Michael Bevan were awarded tenure, and Professors Frank Solomon, Alexander Varshavsky, and Graham Walker were promoted to associate professor. All of these promotions are effective on July 1, 1980.

Professor King was on sabbatical leave of absence from January 1980 until July 1980.

We were pleased to have had the following as visiting scientists in the Department in the past year: Dr. Marvin Gold from the University of Toronto, Dr. James Haber from Brandeis University, Dr. Giorgio Mangianotti from the University of Turin, Dr. Alan Schwartz from Harvard University Medical School, and Ger Strous from the University of Utrecht.

Professor Howard Green received the 1980 Rosenstiel Award for outstanding research in the basic medical sciences. Professor Philip Sharp was the recipient of the National Academy of Sciences US Steel Foundation Award in Molecular Biology. Professor Sharp was also selected to receive the 1980 Eli Lilly Award in Biochemistry. This award is made to a scientist under the age of 36 for outstanding contributions in research in the field of biochemistry.

We were saddened by the death on February 27, 1980, of Dr. Kurt Lion, Professor Emeritus of Biophysics. Dr. Lion was an international authority in the area of instrumentation in biology. He became Professor Emeritus in 1969 when he officially retired from his teaching and other faculty responsibilities.

GENE M. BROWN

Department of Chemistry

Bachelor of Science degrees in chemistry this year were awarded to 38 undergraduates: four in September, four in February, and 30 in June. Most of the graduates will be attending graduate school in chemistry, medicine or related areas, or have been employed by industry. The Master of Science was awarded to four candidates: one in September, one in February, and two in June. A total of 39 Ph.D.s were awarded to 15 candidates in September, 11 in February, and 13 in June. To date, 1,595 Ph.D.s and 384 Master's degrees have been awarded by the Department.

RESEARCH

Almost all areas of modern chemistry are represented in the Department's research programs. A few examples of ongoing research activities are described below.

Professor Glenn Berchtold's current research efforts include the total synthesis of naturally-occurring anticancer agents, the total synthesis of chorismic acid and a search of structurally-related substances that inhibit the metabolism of chorismic acid, and an investigation of the pathway of aromatization of arene 1,2 oxides.

Triptolide and triptolide, two of the three recognized diterpenoid triepoxides of plant origin, are of special interest due to their impressive life-prolonging effects in mice afflicted with the L-1210 lymphoid leukemia. A total synthesis of triptolide and the companion cytotoxic ketone, triptonide, has been completed during the past year. The synthesis is a 23-step sequence from readily available starting materials. Improvements in the synthetic sequence are under investigation in order to provide significant quantities of triptolide to the National Cancer Institute for more detailed studies of its antileukemic effects in animals. A total synthesis of triptolide is under study. A total synthesis of sesbanine was accomplished also during the past year. Sesbanine is a new spirocyclic structure, based on the 2,7-naphthyridine nucleus, isolated from plant extracts that possess antileukemic activity.

Chorismic acid is a central intermediate in the biosynthesis of aromatic amino acids and growth factors in bacteria, fungi, and higher plants. Chorismic acid is a unique dihydroaromatic structure, and the total synthesis is under study in Professor Berchtold's laboratory. The conversion of chorismic acid to the amino acids tyrosine and phenylalanine in the plant world involves an enzyme-catalyzed sigmatropic rearrangement in nature. Structural analogs of chorismic acid have been prepared and are under study with enzymes that metabolize chorismic acid in an effort to determine the structural requirements for the enzyme-catalyzed sigmatropic reaction and in an effort to find substances that act as suicide substrates for chorismate-metabolizing enzymes. These suicide substrates would represent new structures that ought to possess significant antibiotic and antifungal activity, and they should act as plant growth regulators.

Biological hydroxylation of aromatic substrates, in several cases, is known to proceed via initial formation of an arene oxide that subsequently rearranges, without enzyme catalysis, to the phenolic product. A variety of known biological hydroxylations may proceed via initial formation of an arene 1,2-oxide, but none of these arene oxides have been found in nature. These reactions involve ortho hydroxylation with or without migration of the substituent and hydroxylation at the site of the substituent with substituent loss. Current research efforts by Professor Berchtold and his associates involve the synthesis of arene 1,2-oxides, many of which may be biological intermediates, and an investigation of the pathway by which they aromatize to phenolic derivatives. The studies establish the effect of substituents on the direction of ring-opening of the arene oxide during aromatization. In all cases studied thus far with synthetic arene 1,2-oxides, the extent of substituent migration or substituent loss during aromatization supports the suggestion that arene 1,2-oxides are intermediates in biological hydroxylation reactions.

The research of Professor Fenton McFeely's group involves the use of electron spectroscopic techniques to study the properties of molecules adsorbed on solid surfaces. Investigations of the structure of adsorbate-substrate complexes formed via chemisorption are aimed at achieving greater insight into the mechanisms of chemical reactions occurring on the solid surface (catalytic processes) or direct reaction with the surface itself (oxidation-corrosion, semiconductor etching phenomena). A recent study of CO chemisorption of the (311) surface of copper provides an example of these efforts.

During the past few years, the techniques of surface physics have been brought increasingly to bear on the study of chemisorption and chemical reactivity on high-index single crystal surfaces. This is largely due to the superior modeling afforded by these stepped and kinked surfaces to the necessarily highly defective microcrystallites upon which practical catalysis occurs. An important aspect of this problem is to determine whether the richer stereochemistry and differing surface electronic states afforded by stepped surfaces can give rise to modes of chemisorption qualitatively different from those found on ideal closely packed planes. To investigate this question, Professor McFeely and his students have performed the first angle-resolved photoemission investigation of CO chemisorption on a stepped surface, the (311) plane of copper. This surface is made up of alternating two-atom "terraces" of (100) and (111) orientation and therefore affords a high step defect density.

The experiments are in principle quite straightforward. When a molecule on the surface absorbs a polarized photon and emits a photoelectron, the angular dependence of the photoelectron emission intensity allows us to infer the orientation of the molecule. Previous applications of

this technique to ideal surfaces (e.g., (100) and (111) faces) have invariably revealed that CO molecules are oriented perpendicular to the surface. Professor McFeely's results showed that the situation on this stepped surface is much more complex. Molecules were found to bind to each of the (100) and (111) microspheres in a perpendicular configuration, and, in addition, a new form of CO surface coordination was discovered in which the molecules lie flat on the surface in the grooves formed by the steps.

While this new coordination is unknown in transition metal cluster compounds (the closest analog being the iron "butterfly" compounds), it may be extremely important in the mechanism of the Fischer-Tropsch methane synthesis on catalytically active metals. The first step on this reaction is thought to be carbon-oxygen bond scission, and this coordination can facilitate this step in two ways. First, the large interaction between the $2\pi^*$ molecular orbitals and the surface afforded by this configuration will be much more efficient in weakening the CO bond than conventional backbonding. Secondly, the molecule is oriented such that both atoms may be highly coordinated to the surface as the bond is broken. For conventionally bound molecules, this may be achieved only by a presumably activated reorientation step. Experiments to determine if such a complex can actually occur on catalytically active metals are currently in progress.

Professor Rick Danheiser's research involves the development of new synthetic methods and their application in the total synthesis of biologically important substances not readily obtained from natural sources. Target molecules of current interest include neurotoxic alkaloids, anti-tumor antibiotics, and insect sex attractants. An important feature of this research is that each investigation has as its objective not only the synthesis of a particular molecule, but also the development of new, general methods for effecting important synthetic transformations. Recent studies have yielded several powerful new reactions of significant synthetic utility.

The vinylcyclopropane rearrangement is a potentially useful reaction for preparing five-membered rings. This method has previously seen limited application in organic synthesis since the reaction requires temperatures in excess of 500°C and is often complicated by the intervention of side reactions. A new reaction, the "alkoxy-accelerated vinylcyclopropane rearrangement," has been developed in Professor Danheiser's laboratory, which proceeds in high yield at only 0°C, is highly stereoselective, and produces cyclopentane products which are functionally equipped to facilitate further synthetic elaboration. The extension of this methodology to the synthesis of other ring systems is currently in progress.

The utility of vinylketene derivatives in organic synthesis is also being investigated by Professor Danheiser. In principle the Diels-Alder reaction of vinylketenes provides a particularly expeditious route to six-membered ring containing compounds including the anthracycline antitumor agents. Unfortunately, this approach is not feasible since vinylketenes are normally extremely unstable compounds which combine with olefins via [2+2] cycloadditions rather than the [4+2] mode of the Diels-Alder addition. Professor Danheiser and his co-workers have recently developed an efficient synthesis of a new type of vinylketene derivative which exhibits the required properties and reactivity. This unusual substance, trimethylsilylvinylketene, is a stable compound which regiospecifically combines with olefins in Diels-Alder reactions in the desired fashion. The application of this new reagent in natural product synthesis is now in progress.

Trimethylsilyllallenes are another class of novel compounds which have been demonstrated by Professor Danheiser to be valuable synthetic intermediates. New methodology has been developed in which these substances function as uniquely effective "propargylic anion equivalents," and this reaction is currently being applied to the synthesis of olefinic insect pheromones. Another new synthetic method employing these compounds provides a powerful new regiospecific annulation approach to five-membered carbocyclic systems, the scope, and stereochemistry of which is now under investigation.

Professor Irwin Oppenheim and his research group have studied the motion of test particles in fluid baths and have described the conditions under which the correlations between the velocity of the test particle decays as a simple exponential as a function of time. Restrictions must be placed on the mass, size, and density of the test particle for this to be true.

In addition, techniques have been developed for the theoretical study of fluid systems which may be far from equilibrium. The main techniques utilized were nonlinear response, projection operators, and mode-mode coupling.

Exact equations of motion for the distribution function and for dynamical variables in systems which are nonlinearly displaced from equilibrium have been derived and examined. A projection operator was introduced to resolve these equations into a local equilibrium contribution and correction terms. These are of two types: dissipative and fluctuating. They are related by a generalized fluctuation-dissipation theorem.

The dissipative terms are essential for a valid description of transport processes. Simplifications were introduced for systems where the local thermodynamic potentials are slowly varying on the scale of the molecular correlation length. This leads to local transport equations. For the hydrodynamical variables these are precisely the Navier-Stokes equations. The entropy production for a system described by such nonlinear equations is positive semidefinite and vanishes if and only if the system is in equilibrium.

These results were used to study the fluctuation-dissipation theorem in nonequilibrium stationary states arbitrarily far from equilibrium. This theorem was found to have a different form from that found for systems close to equilibrium.

Most of Professor Oppenheim's research has been devoted to the study of steady-state systems in which there is either a constant linear temperature gradient or a constant linear shear. His treatment of fluctuations in these systems led to the surprising result that fluctuations in these systems are qualitatively different from those in equilibrium systems. For example, in the temperature gradient case, the fluctuations in number density at a point are correlated with fluctuations in the momentum density at another point; this correlation decays very slowly, i.e., as $1/r$ where r is the distance between the points. It was predicted that these correlations would affect the light-scattering spectrum in a significant way. These results have been confirmed by experiment. They imply that sound modes in the direction of the heat flux are enhanced whereas those in the opposite direction are depleted.

The general theme of Professor Edward Solomon's research programs in Physical-Inorganic and Bioinorganic Chemistry is the application of spectroscopic techniques to problems of inorganic structure and bonding. Emphasis is placed both on the detailed study of chemically relevant electronic structure problems in highly symmetric transition metal complexes, and on determining the active sites in metalloproteins and heterogeneous catalysts. General goals are the elucidation of unique geometric and electronic structures and the correlation of changes in structure with variations in function.

A major effort has been directed toward the general chemical and spectroscopic study of active sites in copper proteins. These copper sites may be divided into three types, based on their unique spectral properties. Type 1 or "Blue Copper" proteins exhibit extremely intense absorption bands in the red spectral region (hence the name) and very unique ground state electron paramagnetic resonance (EPR) parameters. Polarized electronic absorption and EPR spectral studies have been used on single crystals of the blue copper protein, plastocyanin, involved in photosynthesis. These studies have enabled a detailed understanding of all the unique spectral properties in terms of structural features of the active site. Changes in these spectral properties over a series of type 1 proteins are correlated with variations in the active site structure and reactivity.

Type 2 copper protein sites (e.g., galactose oxidase, dopamine- β -hydroxylase) have spectral properties which are more similar to those of normal copper complexes. However, these are not very useful in a probing function which involves the interaction with small molecules. A general approach for the study of the type 2 copper site has now been developed by Professor Solomon. This involves binding a spectral probe ligand to the copper which yields an intense low energy ligand to metal charge transfer transition. This new absorption feature allows the site to be probed at high resolution through resonance Raman vibrational-electronic studies. The equipment necessary for these studies has been developed in conjunction with the Regional Laser Facility of the MIT Spectroscopy Laboratory.

The type 3, or binuclear copper site, is unique in exhibiting no EPR signal and is diamagnetic to the most sensitive instruments presently available. The complexities associated with these unique spectral features and the binuclear nature of this site have been overcome through the preparation of a series of protein derivatives. These enable systematic variation of the active site as it is subjected to a variety of spectroscopic techniques. The combination of combined chemical

perturbation with spectroscopic probes is leading to correlations of changes in geometric and electronic structure with variation in function over the type 3 copper containing proteins: anthropod hemocyanins (cooperative O₂ binding), mollusc hemocyanins (cooperative O₂ binding and catalase activity), and tyrosinase (monooxygenase).

With this experience on the different types of copper site separately, Professor Solomon's interests have turned to bringing these together in the multicopper oxidases: laccase, ceruloplasmin, and ascorbic acid oxidase. These contain a combination of type 1, type 2, and type 3 copper sites (ceruloplasmin, for example, found in human blood and involved in iron metabolism and copper transport, contains two type 1, one type 2, and two type 3 copper sites). Approaches which will uncouple these sites, enabling selective study of each site as described above, are being developed. Interactions between sites will also be probed in detail.

Professor Solomon and his associates also have been strongly involved in problems relating to active sites in heterogeneous catalysis. The primary interest being the interaction of chemically relevant small organic molecules with metal oxide single crystal surfaces and powders. Catalytically important small molecule-surface complexes are formed which, as with the metalloenzymes, exhibit unique spectroscopic properties compared to known inorganic complexes. Surface-sensitive electron spectroscopic techniques (in particular, UV photoelectron spectroscopy as well as ESCA, Auger and LEED) are combined with controlled chemical perturbation in these studies.

The major emphasis here has involved the study of the chemisorption of CO on four low-index surfaces on ZnO, an active methanol catalyst. These surfaces have significant differences with respect to their coordination unsaturation; thus, a correlation between the adsorption behavior and the surface structure enables the geometric requirements for chemisorption to be determined. The adsorption was found to be reversible, and measurements of the equilibrium coverage as a function of temperature and pressure demonstrated that the bonding interactions were very similar on all four surfaces. Chemisorbed CO is readily displaced by NH₃, indicating the involvement of zinc ions in the bonding of CO to the surface. This is strongly supported by the relative CO coverage of the four surfaces under equivalent conditions, which generally correlates with the availability of unsaturated zinc sites.

Professor Mark Wrighton's research program covers aspects of inorganic photochemistry, surface chemistry, and photoelectrochemistry. Research in these areas may have practical consequences in the fields of catalysis and solar energy conversion. Objectives of the research include elaboration of known light-driven processes, establishment of mechanisms of catalytic reactions, and understanding of charge transfer across interfaces. One of the recent highlights of the research has concerned the synthesis and characterization of photosensitive interfaces for use in converting light energy to electrical energy or to chemical energy in the form of oxidation, and reduction products resulting from light-driven charge transfer reactions at the designed interface. Two important concepts have been demonstrated: 1) chemical derivatization of an electrode surface for the purpose of protection against corrosion has been illustrated for n-type semiconductor photoanodes used in photoelectrochemical cells for the conversion of light to electricity; and 2) significant rate acceleration for a heterogeneous electron transfer process has been shown for hydrogen formation from water reduction at an illuminated interface by designed chemical modification of the photosensitive surface.

N-type semiconductors have been established to serve as photoanodes in photoelectrochemical cells for the conversion of light to electricity or fuels in the form of the electrolysis products. However, illumination of photoanode materials often leads to irreversible, efficient corrosion of the electrode, and the lifetime of the energy conversion device is severely limited. Research reported by Professor Wrighton's group in 1976 established that the corrosion could be effectively suppressed by using appropriate oxidation-reduction reagents in the electrolyte solution. Today, this technique has been exploited to give cells having greater than 12 percent efficiency for the conversion of sunlight to electricity. Among the photoanode materials that could be "stabilized" by judicious choice of reagents is n-type silicon, which can be stabilized by using ferrocene as a reducing agent in cells employing a non-aqueous solvent. Use of ferrocene in water is precluded by its insolubility in water. Even a trace of water is a problem for n-type silicon, since the photocorrosion reaction in this case is the photooxidation of the silicon-to-silicon oxide where the oxygen atoms of the oxide come from water molecules. The role of ferrocene is to become oxidized to ferricenium at the illuminated n-type silicon photoanode at such a rapid rate that the

silicon itself cannot be oxidized to silicon oxide. These observations led Professor Wrighton to set out to covalently anchor ferrocene to the surface of the photoanode. It was hoped that by anchoring ferrocene to the surface one could stabilize the silicon in water solvent: the surface-confined ferrocene could be photooxidized to the ferricenium form and this photogenerated, surface-confined oxidizing reagent could then in turn oxidize some solution species that alone would be incapable of stabilizing the n-type silicon. Anchored ferrocene-centered reagents have been shown to stabilize n-type silicon in aqueous electrolyte solutions. More importantly, it also has been shown that light absorbed by the silicon photoanode can be used to oxidize any reagent that can be oxidized by ferricenium. Thus, the surface-derivatized electrode does far more than the "naked" (non-derivatized) electrode. This is one of the few cases where a designed interface has succeeded in favorably altering charge transfer processes.

P-type semiconductors serve as photocathodes in photoelectrochemical cells. Unlike the n-type semiconductor materials they do not suffer gross photocorrosion reactions. Much attention has been given to the use of p-type semiconductors for photochemical reduction of water to form hydrogen. However, the demonstrated efficiencies have been very small until quite recently. Professor Wrighton recognized that a key factor in the inefficiency is the slow speed of hydrogen evolution from most surfaces. Experiments show that p-type semiconductors such as silicon, gallium arsenide, and indium phosphide do suffer from poor kinetics for hydrogen evolution. Chemical derivatization of the surfaces of such materials has led to significant improvement of the kinetics for hydrogen evolution. For these materials the chemical derivatization first involves surface attachment of an N,N'-dialkyl-4,4'-bipyridinium reagent. Surfaces can be functionalized with polymeric amounts of the reagent, and each oxidation-reduction monomer bears a +2 charge that is balanced by counterions that are also bound to the electrode surface. The counterions can be exchanged rapidly to yield surfaces having different properties. The most interesting exchange reaction involves the incorporation of a platinum-centered complex that can be subsequently reduced to a catalytically active form which accelerates the evolution of hydrogen when the electrode is illuminated in an aqueous electrolyte. Efficiency for the conversion of monochromatic visible light to chemical energy in the form of hydrogen from water is significantly improved from less than 0.1 percent for the naked surfaces to greater than 5 percent for the chemically derivatized surfaces.

The two examples of favorably altering interfacial, light-driven charge transfer reactions represent a start toward designed interfaces for solar energy conversion. Practical and fundamental questions of importance remain to be addressed in this research area. Success depends on an interdisciplinary effort involving sophisticated physical techniques such as Auger spectroscopy and electron microscopy on the one hand and challenging, complex chemical synthesis on the other. Structure and reactivity -- central to chemistry as a whole -- is the heart of the basic research of interfaces. Interface structures play a key role in many practical systems including solid state electronic devices, batteries, and heterogeneous catalytic processes to name a few. Designed interfaces under study may lead to sufficient understanding that deliberate manipulation of reactivity becomes possible.

FACULTY

Professor William Orme-Johnson joined the faculty from the University of Wisconsin. Professor John Ross left the Department to accept a position at Stanford University, and Professor Ellen Henderson left to join the faculty at Georgetown University.

Professors Richard Schrock and Jeffrey Steinfeld were promoted to professor.

Professor George Whitesides was appointed the first holder of a new chair established by the Grace Foundation, Inc. in honor of Robert T. Haslam and Bradley Dewey. Prior to his appointment to the Haslam and Dewey Chair, Professor Whitesides held the Arthur C. Cope Chair in Chemistry. Professor William Rastetter was named as the first Roger and Georges Firmenich Career Development Assistant Professor of Natural Products Chemistry.

In April, Professor John Deutch returned from leave of absence to take up the Arthur Clay Cope Professorship in Chemistry. Prior to that he had been serving as Under Secretary in the US Department of Energy.

Drs. Nannete Orme-Johnson and Catherine Costello were appointed principal research scientists.

We were saddened by the deaths of Professor Emeritus Stephen Simpson and Professor Robert Woodward of Harvard, both of whom were departmental alumni. Professor Simpson had retired in 1959 after many years of service on the faculty. Professor Woodward, the recipient of the 1965 Nobel Prize in Chemistry, was a former member of the department's visiting committee.

Professor Robert Field was awarded the first H.P. Broida Prize by the American Physical Society. Professor Emeritus John Sheehan was given an honorary degree by Stevens Institute of Technology at a symposium recognizing his research contributions. Professor John Deutch received the Distinguished Service Medal.

Professor Dietmar Seyferth was awarded an honorary degree, Docteur Honoris Causa, by the University of Aix-Marseille III.

The tenth anniversary of the dedication of the Camille Edouard Dreyfus Building was celebrated in April with a dinner attended by representatives of the Dreyfus Foundation and other donors to the building.

Visiting faculty and scientists were as follows: A. Aruchamy, University of Roorkee, Roorkee, India; Joel M. Bowman, California Institute of Technology; John H. Brophy, University of Leeds, England; Itamar Burak, Tel-Aviv University, Israel; Stephen J. Carter, London University; Cheng A. Chang, Wellesley College; Bakshish Chauhan, University of Guelph, Ontario, Canada; Patricia A. Clark, Vassar College; Harold H. Freedman, Dow Chemical Company; William E. Geiger, University of Vermont; Laurence D. Goldstein, Brown University; Tatsuo Kaiho, Osaka University, Japan; Daniel H. Katayama, Air Force Geophysics Laboratory; Yehuda Lapidot, Hebrew University, Israel; John W. Lehman, Lake Superior State College; Raphael D. Levine, Hebrew University, Israel; Michel A. Lhermitte, Université de Lille, France; Mou-Shuing Lin, Harvard University; Erwin London, Cornell University; David L. McFadden, Boston College; Beatrix Meeusen, K.U. Louvain, Leuven, Belgium; Jeffrey Y.P. Mui, Union Carbide Corporation; Arno O. Pähler, University of Göttingen, Germany; George S. Patterson, Suffolk University; Elke Pinn, University of Göttingen, Germany; Arnet L. Powell, Office of Naval Research; Christian C. Prudhomme, Université Louis Pasteur de Strasbourg; Vernon N. Reinhold, Harvard Medical School; Robert N. Ross, Cornell University; Harumi Sato, Tohoku University, Sendai, Japan; Li-Cheng Song, Nankai University, Tianjin, China; Tatsuo Toyoda, Kyoto University; Daniel D. Trafficante, Yale University; Frank Vellaccio, College of the Holy Cross; Reiner K. Wertheimer, Technical University, Munich, Germany; Frederik Wiegel, University of Amsterdam; Dieter B. Wildenauer, University of Munich, Germany; Robert M. Williams, Harvard University.

The Department was privileged to sponsor lecture series provided by the Arthur D. Little, T.Y. Shen, and Karl Pfister professorships. Professor Michael Fayer of Stanford University delivered A.D. Little Lectures in physical chemistry on the topics: "Processes Involving Excited States of Molecules: What Optical Excitations Do," "Lineshapes and Beyond," and "Transient Grating Experiments." A.D. Little Lectures in organic chemistry were presented by Professor Yoshito Kishi of Harvard University who spoke on "The Total Synthesis of Mitomycins," and "The Total Synthesis of Polyether Antibiotics." Professor Heinz G. Floss of Purdue University was the T.Y. Shen Visiting Professor. His topic was "Biosynthesis of Ergot Alkaloids (Or the Story of the Unexpected)," "Studies in Antibiotic Biosynthesis," and "Stereochemistry of Pyridoxal Phosphate-Catalyzed Enzyme Reactions." The Pfister Lecturer was Professor A.I. Scott of Texas A & M University who lectured on "¹³C-NMR as a Probe for Enzyme-Catalyzed Reactions and Metabolism in Live Cells," and "Recent Progress and Problems in Tracking Nature's Pathway to Vitamin B₁₂."

JAMES L. KINSEY

Department of Earth and Planetary Sciences

The Department of Earth and Planetary Sciences continues to be able to attract and financially support a consistent number of graduate students. We had a total of 113 graduate students enrolled during the 1979-80 academic year. Of this figure, 68 students were in Course XII, and 35 in Course XII-W -- the Joint Program in Oceanography with the Woods Hole Oceanographic Institution. Of the students in Course XII, 85 percent are supported by research and teaching assistantships, and 15 percent by fellowships which are either departmentally or nationally awarded. (One student is self-supporting.) In the Joint Program, all of the graduate students are supported financially, either by fellowships or research funds.

Our undergraduate enrollment was 48 students (14 sophomores, 17 juniors, 16 seniors, and 1 fifth-year student) for the past academic year. Our undergraduate subjects continue to attract a good number of non-majors, most frequently from the Physics and Chemistry departments, and a large contingent of Wellesley College students participate in our geology courses.

The following degrees were awarded during the period September 1979 through May 1980: 19 Bachelor of Science, three Master of Science, eight Doctor of Philosophy (XII), and six Doctor of Philosophy (XII-W).

CURRICULUM

We had Dr. Richard Sillitoe as our Crosby Visiting Professor this year. Professor Sillitoe is a consulting geologist, based in London, with world-wide experience in mineral prospecting and mineral resource analysis. He offered a very well attended course (both by undergraduate and graduate students) which dealt with the subject of plate tectonics as a framework for the genesis of ore deposits. This course was given during the spring semester of the 1979-80 academic year.

A major curriculum revision in physical oceanography is being studied for at least partial implementation in the coming academic year.

RESEARCH

The Department of Earth and Planetary Sciences is very diverse and covers most fields of earth and solar system physics, chemistry, and geology. A few highlights by broad category are all that can be mentioned here.

Geology and Geochemistry

Professor Clark Burchfiel and his students have been continuing their long-standing field mapping of Precambrian rocks of western Norway. Based upon the accumulated data, they have been able to show that the older Precambrian rocks are reworked portions of the Baltic shield, and that the nappe structures of the Caledonian mountain belt have come from above and west of the Precambrian rocks. In addition, the intense Caledonian deformation and metamorphism has paradoxically left the older basement rocks almost in their original condition. This work will provide important insight into the behavior of the deeper crust during major mountain-building activity (orogeny).

The group under Professor Roger Burns has continued active in mineral spectroscopy and manganese nodule research. High temperature Mössbauer and electronic spectra of minerals have

been shown to have important applications to remote sensing measurements of planetary surfaces, and, closer to home, in applications to solid-state chemistry for interpretation of color, magnetism, and electrical conductivity of minerals.

The nature of the mantle source of oceanic island lavas is the topic of continuing geochemical work by Professor Fred Frey and his group. Their work on the basalts of Oahu defines the composition of the source, the range in the degree in melting required to generate the various lavas, and the nature of residual minerals remaining in the mantle after melting. They have shown that the source composition required differs significantly from that presumed for average mantle composition, and requires complex mantle events to create such a local source. Professor Timothy Grove and his colleagues, in his newly established laboratory, have been conducting research in experimental igneous petrology involving the phase equilibrium and kinetics of basalts. Phase equilibrium studies have been used to develop a solution model for pyroxene; the model allows calculation of the equilibria between pyroxene silicate liquids and pyroxene and olivine. The equilibria will provide useful tools for interpreting igneous processes, for estimating crystallization temperatures of basalts, and for calculating fractional crystallization of magmas.

The ion microprobe facility, which was installed in the Department two years ago, and which is operated by an MIT/Harvard University/Brown University consortium, has been successfully running under the general supervision of Professor Stan Hart. There have been a number of geochemical applications of this powerful instrument. For example, Professor Hart and Principal Research Scientist Nobumichi Shimizu have managed to contour the lead isotope ratios of a single small, one centimeter, galena crystal from the Mississippi Valley lead ore province. These ratios show remarkably large and regular variations throughout the crystal with a range of variation almost as large as the total variation found throughout the entire mine from which the crystal came. These results show that the ore-forming fluids were continuously changing in isotopic composition during the crystallization history of the ore minerals. They expect to be able to establish a complete picture of hydrothermal flow patterns in the mine and the nature of the sources from which the lead in the ores was derived.

Professor Frank Spear and his colleagues have made a new projection of the composition space for meta-volcanic rocks which incorporates a three-dimensional representation of four of the principal chemical components of the rocks, instead of the three conventionally used. The new projection successfully explains most of the observed mineral associations in meta-volcanic rocks. Current work on sulfide mineral assemblages in these rocks indicates that desulfurization reactions may be important in prograde metamorphism. Sulfur released from such reactions is apparently carried off by a hydrothermal fluid phase and may later be involved in ore deposition processes.

Much of the geochemical work referred to here obviously reflects the growing interest in geology and geochemistry in hydrothermal processes and their relation to mineral ore formation. Additional work in this area is referred to under oceanography, later in the report.

Geophysics

A growing interaction with the petroleum and mineral exploration industries is reflected in the research interests of Professor Nafi Toksöz and his group. They have been continuing their studies of plate tectonics, sedimentary basin evolution, rock physics, and wave propagation as applied to oil and mineral location. As a result of this work there has been an increase in industrial support for research and graduate student assistantships. We anticipate a large growth in this interaction over the next several years as a part of the increasing national concerns in these areas.

The two-volume work *Quantitative Seismology* was published by Professor Keiiti Aki and his coauthor Paul Richards this past year. The books are an outgrowth of Aki's teaching and research over the past years at MIT. It is anticipated that they will become the definitive work in seismology for the next several years, at least. In recent work, Aki's three-dimensional inversion method has been applied to the United States Geological Survey seismological network data in central California. They have found that the Farallon plate, under the western United States where it has been subducted, has a lower seismic velocity than the surrounding mantle. This result is a considerable surprise and the consequences of the discovery will undoubtedly

be far-reaching. The method is being widely applied to various arrays around the world to produce results in regional tectonics and volcanism.

Professor Sean Solomon and graduate student Anne Trehu recently completed a study of about 50 microearthquakes located on the Orozco Fracture Zone, in the east central Pacific, during the multi-institutional Project ROSE (Rivera Ocean Seismic Experiment). The most important new result is the surprisingly large focal depth of many of the earthquakes -- up to 17 kilometers below the sea floor. This finding was contrary to the expectation that all seismic activity would be confined to the upper five kilometers or less because of the predicted high temperatures at shallow depths for the Orozco transform fault, which offsets a fast spreading ridge by less than 100 kilometers.

Professor John Sclater, working with Principal Research Scientist Barry Parsons, has been able to show that continental and oceanic heat flow and subsidence data are compatible with models of the lithosphere as a thermal boundary layer, having the same temperature at depth under both continents and oceans. Using this concept, they have been able to construct a model for the formation of continental shelves and basins. With the model, it is possible to investigate the degree of thermal maturity of organic-rich sediments in areas of thick sediment accumulation with obvious applications to the formation of petroleum deposits.

The preliminary hypothesis that microcracks are the pathways through which uranium and other radioisotopes migrate in granitic rocks has been developed by Professor Gene Simmons and his group. This hypothesis has potential applications for the exploration of uranium reserves, in situ mining, and in the problem of disposal of high level radioactive wastes.

Workers in Professor William Brace's rock mechanics group are doing experiments on mechanical and transport properties of fine-grained earth materials at high pressure and at temperatures ranging from ambient to 1300°C. Such fine-grained minerals occur along fault zones, and knowledge of their mechanical properties is an important way to increase understanding of earthquakes. They have been successful in duplicating metamorphic conditions of temperature, pressure, and chemical fugacities, so that fully dense marbles have been fabricated, and they are hopeful that fully dense quartz rocks can also be made. Lucile Jones, a graduate student in the rock physics laboratory who is also proficient in Chinese, spent five months in Peking during 1979 collecting seismic and well log data for analysis. She returned again in June 1980 for an additional three months work during the summer.

Oceanography

Chemical oceanography Professor Ed Boyle has developed a method for investigating the nutrient chemistry of the ocean over the past million years. Using fossil microorganisms, he will be able to apply this method to derive a better understanding of long-term changes in ocean circulation and the rate of climatic fluctuations. Professor John Edmond's group successfully sampled the 350°C hot springs on the East Pacific Rise from the submersible ALVIN. The hot springs are actively forming sulphide ore deposits of the type now mined on land for base metals. They have never before been seen forming. The chemical composition of the existing solutions provides direct insight into the processes of ore metal transport, and promises to resolve directly any of the outstanding problems in this area of economic geology. Furthermore, the scale of hot springs activity worldwide is such that convective recycling of sea water, through the spreading centers by high temperature reaction with the new basalts, exerts a profound influence on the chemistry of the ocean on a geological time scale.

Professor Charles Eriksen has been studying the physical oceanography of the western equatorial Pacific Ocean. He has shown from vertical profiles of current and density that there are deep current reversals confined to the equator similar to those found in the Indian Ocean. He has modeled them successfully as a sum of equatorial Rossby, Kelvin, and mixed Rossby gravity waves with periods of at least a year. These motions verify the existence of the equatorial waveguide and represent a response of the deep equatorial ocean to wind forcing. Professor Carl Wunsch and his collaborators have continued their work on determining the circulation of the North Atlantic Ocean. They have produced consistent inverse models of the large-scale circulation of the ocean that are both geostrophic and water-mass conserving. Using the models it is possible to compute the meridional heat flux of the North Atlantic Ocean. The results suggest that there is no fundamental

discrepancy between the values required by meteorologists from their atmospheric residuals and those determined by direct means in the ocean.

Planetary Sciences

The equatorial radius and ellipticity of Uranus at the 10^{14} molecules per cm^3 density level in the upper atmosphere have been obtained by Professor James Elliot. Using the Uranian rings as a reference coordinate system, they obtained a radius of 26,000 kilometers, an ellipticity of 0.033, and a rotation rate of 12.8 hours.

Professor John Lewis and his co-workers have continued their work on the origin, evolution, composition, and structure of planetary atmospheres. They have assessed the impact of lightning and thunder shock waves on the Jovian atmosphere from Voyager data, and have studied the theory of production of organic molecules in high-temperature shocks, leading to the conclusion that such processes are incapable of providing detectable amounts of organic matter (1 part per billion) in Jupiter's atmosphere.

Professor Charles Counselman and his collaborators have begun using very long baseline interferometric techniques to determine the relative motions of the North American and Eurasian plates. These involve trans-Atlantic radio wave measurements. Other results show that within the North American plate, the distance between a point in Massachusetts and one in California, east of the Pacific plate boundary, must have changed by less than about three centimeters in the last two years. This and the trans-Atlantic measurement are part of a program eventually expected to extend to several other continents. A major effort directed at mapping and understanding the surface of Venus has been continued during the past year by Professor Gordon Pettengill. Using the Pioneer Venus Orbiter radar he has observed for the first time the relief and radar scattering characteristics of 93 percent of the surface of Venus. Major "continents" as well as volcanic and tectonic activity have been disclosed.

FACULTY

The Head of the Department, Professor Carl Wunsch, was on leave at Harvard University during the spring semester. Professor Clark Burchfiel served as Acting Head during that period.

We have added one new faculty member to our ranks during the past year. Dr. Timothy L. Grove joined our department as Assistant Professor of Petrology in July 1979. Prior to coming to MIT, Professor Grove was a research associate at the State University of New York at Stony Brook. His field of expertise is experimental igneous petrology, and he fills a major gap in our program which was created by the retirement of Professor Emeritus Harold Fairbairn several years ago and the departure of Professor John S. Dickey, Jr. in May 1979.

Professor Peter Molnar has been on sabbatical leave, spending the fall semester at the Institut de Physique du Globe in Paris and the spring semester at the University of Cambridge. Professor Tanya Atwater took a leave of absence and has spent the past year at the University of California at Santa Barbara. Dr. Frank Press, Robert R. Shrock Professor of Geophysics, remains on leave as Science Advisor to the President.

We made two appointments to the rank of principal research scientist, bringing the total number of such individuals in our department to three. Dr. Barry E. Parsons was promoted in July 1979, and Dr. Robert D. Reasenberg in January 1980.

Honors

Professor Sean Solomon was elected a Fellow of the American Geophysical Union.

Professor Peter Molnar was awarded a Guggenheim Fellowship in partial support of his sabbatical leave.

Professor Gordon Pettengill received the NASA Exceptional Scientific Achievement Medal for his work with the Venus spacecraft.

CARL WUNSCH
CLARK BURCHFIEL

Department of Mathematics

During the 1979-80 year there were 129 undergraduate majors in Mathematics and 110 graduates majoring in Mathematics. Forty-five Bachelor of Science degrees in Mathematics were granted during the year. There were five recipients of the Master of Science and 24 recipients of the Doctor of Philosophy in Mathematics.

UNDERGRADUATE AND GRADUATE PROGRAMS

The team from the Mathematics Department at MIT placed first in the nationwide William Lowell Putnam Mathematical Competition. The winning team consisted of three mathematics majors: Daniel D'Eramo, Miller Puckette, and Michael Roberts, all of the Class of 1980. Mr. Puckette also ranked first individually in the competition.

The Student Mathematics Committee is a newly formed group of undergraduates and graduates who are interested in improving Departmental activities involving students. For example, they have sent representatives to the Undergraduate Committee, served coffee and donuts at Registration, and organized two successful advisor-advisee teas.

The Department developed a new theoretical option for majors in Mathematics, to give more majors the guidance and satisfaction of a distinctive program.

Professor Emeritus George Thomas, author of the calculus textbook, gave a lecture in lieu of the regular Friday afternoon calculus lectures. Eight hundred students received the talk enthusiastically, and it took Professor Thomas almost an hour to fill the requests for autographs. His talk was followed by a dinner at the Student Center.

IAP activities included the Second Annual Mathematics Department Music Recital and a talk on X-rays, Needles, and Nobel Prizes.

One innovation was the televised differential equations recitation which Instructor Steven Bell held every Wednesday night. Students watching on the MIT cable system could call in with questions.

After five years, Professor Michael Artin stepped down on July 1 as chairman of the Graduate Mathematics Committee. Professor Artin's lengthy period of service in this position has been marked by the energy and exacting standards he brought to it. He will be succeeded by Professor Steven L. Kleiman.

FACULTY

The Department has appointed Daniel Z. Freedman (theoretical physics) as a Professor of Applied Mathematics. Four Assistant Professors of Applied Mathematics also have been appointed. Ravindran Kannan, Philip Marcus, Manoj Prasad, and Michael Sipser. Assistant Professor Leonard A. Adleman (computer science) has been promoted to Associate Professor of Applied Mathematics.

Instructor Ira Gessel (combinatorics) and Lecturer Gregory R. Baker (fluid dynamics) have been promoted to Assistant Professors of Applied Mathematics. Instructor Gunther Uhlmann (partial differential equations) has been promoted to Assistant Professor of Mathematics.

Professor Hartley Rogers has resigned his position as Associate Provost in the Institute to return to full-time research and teaching in the Department.

Faculty members on leave during the past year were: Professor Kenneth M. Hoffman; Professor Kleiman (spring); Professor of Applied Mathematics Willem Malkus; Professor Irving E. Segal (spring); Professor Harold M. Stark (fall); Assistant Professor of Applied Mathematics Rudolpho R. Rosales.

The following people held visiting appointments during the past year: Professor Jean Leray (College de France); Associate Professor Richard Shore (Cornell); Assistant Professor Mark A. Adler (University of Wisconsin at Madison); Professor Thomas Cover (Stanford); Professor Arthur Albert (Boston University); Professor Richard A. Olshen (University of California at San Diego); Professor Bardley Efron (Stanford); Professor Giuseppe Bertin (Scuola Normale Superiore, Pisa).

Professor Daniel G. Quillen was awarded the Norbert Wiener Professorship in Mathematics. Professor Herman Chernoff was elected Fellow of the American Academy of Sciences.

A special conference was held on October 24-26, 1979 at MIT to honor Professor Segal on the occasion of his 60th birthday. Twelve prominent mathematicians presented lectures in the four areas in which Professor Segal has made major advances: harmonic analysis and operator algebras; functional integration and the mathematical theory of quantum fields; nonlinear evolutionary partial differential equations; and fundamental physics. Professor Segal was also the recipient of the Humboldt Award from the Alexander von Humboldt Foundation in West Germany. He also was invited to address the 50th Jubilee Congress of the Australian and New Zealand Association for the Advancement of Science in Adelaide, Australia in May 1980.

Professor Franklin Peterson is visiting the People's Republic of China for a four-month period as a guest of the Institute of Applied Mathematics and Systems Science of the Chinese Academy of Sciences. He is sponsored and supported by the Committee on Scholarly Communications with the People's Republic of China (of the National Academy of Sciences) as a part of the US-Chinese exchange program.

Institute Professor Chia Chiao Lin was in the People's Republic of China from August 30 to October 8, 1979 to give a graduate course in Applied Mathematics. His visit was a part of the increasing cooperation in all areas of science and technology between Chinese universities and MIT. Professor Lin also was chosen as the first recipient of the American Physical Society's Fluid Dynamics Prize, sponsored by the Office of Naval Research. The prize, established to recognize "outstanding achievement in fluid dynamics research," was awarded in November 1979.

The Mathematics Department is also pleased to note the marriage in January of Professor Victor Kac to Professor Michele Vergne. Professor Kac, from Russia, and Professor Vergne, from France, met when they became colleagues in the Department.

RESEARCH

The members of the Mathematics Department carry out a variety of research efforts in an unusually wide set of fields in pure and applied mathematics. A small sampling of some of these follows.

Institute Professor Lin and his collaborators have been concerned with the behavior of spiral modes in galaxies. Recently, it has become possible to calculate unstable spiral modes in galaxies both in the stellar model and in the gas dynamical model. The asymptotic theory gives good understanding of the mechanisms, as well as reliable results comparable to those obtained from the "exact" theory. A movie made by a superposition of these modes yields quite realistic looking

spiral structures. Application of these theories towards a dynamical classification of galaxies is being carried out. The study of the dynamical mechanisms involves many interesting mathematical issues which also occur in hydromagnetics and in plasma dynamics.

Professor Uhlmann has been investigating partial differential equations with conic type singularities in the characteristic variety; specifically, Maxwell equations in a biaxial crystal in order to understand the phenomenon of "conical refraction" and the wave equation for the harmonic oscillator in several dimensions. He is also studying pseudodifferential equations whose principal symbol is a product.

Professor Richard Stanley has been concerned with applications of modern mathematical techniques to combinatorial problems. In 1752 Euler proved his famous formula $V - E + F = 2$ (actually known to Descartes 100 years earlier) concerning the number of vertices, edges, and faces of a planar map. Subsequently, geometers and combinatorialists have devoted considerable effort to extending this result to higher dimensions and to more general objects. An outstanding open problem in this area was McMullen's conjectured necessary and sufficient condition on the number of i -dimensional faces of an n -dimensional simplicial convex polytope. In 1979 Lee and Billera of Cornell University proved the sufficiency of this conjecture and several months later Stanley proved necessity. Stanley's proof used deep results from algebraic geometry such as the theory of toroidal embeddings and the hard Lefschetz theorem, and provides a surprising application of a highly abstract theory to a concrete combinatorial problem.

Professor Segal's group has continued a multifaceted approach to problems in fundamental physics that may be amenable to treatment by mathematical analysis. Cosmology, quantum field theory, and elementary particles are the main fields of application. Group and operator theory, functional integration, and computational statistics are the main techniques employed. Currently forthcoming work includes empirical studies of both low-redshift galaxy and high-redshift X-ray quasar data, showing an excellent fit with the chronometric redshift theory due to the group; a restoration of conservation of parity on the basis of its reinterpretation in the chronometric theory; and mathematical studies of the existence, stability, and quantization problems for wave equations, including nonlinear relativistic cases.

Professors Adleman and Adi Shamir have been involved, along with Professor Ronald Rivest of the Department of Electrical Engineering and Computer Science, in the application of complexity theory to cryptography. They have obtained a number of surprising results and are currently developing an integrated circuitry capable of implementing their encoding scheme.

Professor Sigurdur Helgason has been working on the Radon transform along with applications to partial differential equations; and on the X-ray transform which has applications to tomography.

Professor Gian-Carlo Rota has pursued research in invariant theory, especially as it relates to combinatorics via Young tableaux. He has worked with N. Metropolis of Los Alamos Scientific Laboratories on the algebraic aspects of computer arithmetic. In addition, he has developed results relating to sequences of binomial type, the theory of Wronskians, and other areas of mathematics.

Professor Sy D. Friedman has continued his research in logic, specializing in applications of set-theoretic methods to problems in higher recursion theory.

The Statistics group in the Mathematics Department was engaged in a wide variety of work in pure and applied areas which ranged from a survey paper presented by Professor William DuMouchel on inference on stable distributions, and Instructor Richard Davis's paper on extremes of one-dimensional diffusions; to a nonparametric estimate of the slope of a truncated regression (relevant to the current controversy on Hubble's Law) by Dr. P.K. Bhattacharya, Professor Chernoff, and Professor S.S. Yang of Kansas State University. Contributions by visiting faculty, junior faculty, and students involved cluster analysis, pattern recognition, and time series, and applications to nuclear engineering, oceanography, and medicine.

DANIEL J. KLEITMAN

Department of Meteorology

The Department of Meteorology has had a long history of research and teaching in physical oceanography. Dr. Carl-Gustaf Rossby, who founded the Department in 1928, was recognized as a leader among oceanographers as well as meteorologists. From the outset, a number of the theses completed in our Department have dealt with oceanographic topics, and during the past 20 years we have offered the degrees of S.M. and Ph.D. in Oceanography. In further recognition of this aspect of our work, our name will change as of July 1980 to the Department of Meteorology and Physical Oceanography.

The past year has seen the addition of three new assistant professors to our faculty. These are Dr. Mark A. Cane, whose work has dealt with the equatorial oceanic circulation, Dr. Richard E. Passarelli, who is a cloud physicist, and Dr. Raymond T. Pierrehumbert, whose interests have been in geophysical fluid dynamics. In addition, Dr. John E. Hart has been with us as a visiting professor, while Dr. Robert W. Burpee has been and will continue to be with us as a visiting associate professor.

Professor Jule G. Charney's work continues to receive international recognition. At the annual meeting of the American Meteorological Society he received the Society's Cleveland Abbe Award for outstanding service to the field of meteorology. He was also elected to the Honorary Fellowship of the Indian Academy of Sciences.

Our enrollment during the past year has been 53 graduate students, of whom 41 were pursuing degrees in meteorology and 12 in oceanography. Four of these students are women; 19 are foreign students. Five Ph.D.s and nine S.M.s were awarded.

RESEARCH

Professor Burpee has been studying the structure of large-scale, wavelike disturbances that form over Africa and propagate westward across the Atlantic. He is investigating the importance of these disturbances in accounting for western African precipitation. Each summer about four of these disturbances develop into hurricanes as they cross the Atlantic. He is attempting to determine some of the factors that lead to the intensification of these disturbances, using analyses of conventional meteorological data and special aircraft radar observations.

Dr. Burpee is also investigating the structure of the south Florida seabreeze circulation, and the meteorological parameters that account for the variability in the amount of rainfall produced in the sea breeze convergence zones during the summer. This work is designed to provide a physically and statistically meaningful basis for evaluating rainfall enhancement projects that have been conducted in south Florida since 1970.

Professor Cane has been investigating large-scale atmosphere-ocean interactions, with emphasis on the equatorial oceanic circulation and its temporal variations. He also has been studying satellite-derived oceanographic data, with attention to its potential for weather and marine forecasting.

Professor Charney has extended his work on multiple atmospheric equilibrium states, and has found that such equilibria continue to exist when his model is generalized to include topography with an arbitrary zonal wave-number spectrum. He has compared these more realistic equilibria with observed states of the atmosphere, and found that there is one which resembles the observed mean atmospheric state and another which resembles the "blocking" situations which frequently develop. He also has extended his original model to include differential heating. This has the effect of increasing the number and diversity of equilibrium states that can exist,

and of making them more like observed states, which are maintained largely by the atmosphere's available potential energy. In this work he has been collaborating with the staff of the Modeling and Simulation Facility at NASA's Goddard Laboratory for Atmospheric Sciences.

Professor Glenn Flierl has conducted research on the theory of oceanic motions of horizontal scales extending from the mesoscale (around 100 kilometers) to entire ocean basins. He is particularly interested in the theory of two-dimensionally isolated nonlinear eddies, the stability of such eddies to infinitesimal and finite amplitude perturbations, and the applications of these general concepts to energetic eddies such as Gulf Stream rings. The properties of nonlinear flows perturbed by finite-amplitude topography or coastline shape are being examined with applications to the Kuroshio meander and blocking events in the atmosphere.

In addition, he is constructing models of the distribution and effects of pollutants dumped in deep-water oceanic gyres. Understanding these problems requires simultaneous consideration of the physics, chemistry, and biology of the relevant regions.

Dr. Claude Frankignoul, a research associate, has been investigating large-scale interactions of the ocean and the atmosphere in middle latitudes. The main emphasis of his work is on climate variability, sea-surface temperature anomalies, and quasi-geostrophic oceanic eddies.

The US Executive Office for POLYMODE, a bilateral US/USSR program to study mesoscale dynamics in the ocean, is maintained within the Meteorology Department. Robert H. Heinmiller is the US Executive Manager. The program involves investigators at approximately 12 US and five Soviet institutions, and its goal is to achieve a better understanding of the role of eddy processes in the ocean on scales of 50 to 5,000 kilometers. The scientific program includes experiments, numerical modeling, and theoretical elements. The major part of the field program was completed in late 1978. Data synthesis, analysis, and interpretation is continuing.

Professor Edward Lorenz, with the collaboration of Dr. James Curry, a postdoctoral associate, has been investigating the properties of attractor sets of low-order mathematical models of the atmosphere. For suitably formulated models these sets are bounded, and most of their points represent states of approximate geostrophic equilibrium. Professor Lorenz is also attempting to establish the applicability of low-order models to moist circulations. Such models would contain water-vapor and liquid-water content as variables, and their physics would include the thermodynamic and radiative properties of water.

Professor Erik Mollo-Christensen has been studying nonlinear wave processes in the atmosphere and the ocean. The analysis of a recently performed series of wind-wave experiments is yielding a number of novel results concerning couplings of wave fields and wind fields, wave group dynamics, and certain bifurcation processes. Wave-group interaction is also being experimentally observed, and it appears possible to attain wave-group fusion under suitable circumstances. Wave-group splitting has been found to occur under conditions where third-order analysis does not predict splitting.

Professor Mollo-Christensen is also setting up a computer-image processing system, which will allow him to analyze surface waves, internal waves, and other oceanic processes. Other problems under study include multi-dispersive wave fields, discontinuities in nonlinear edge waves, spar-buoy stability, rectification of tidal flow through sea inlets, and wave-group refraction by currents and bottom topography.

Professor Reginald Newell and his collaborators are engaged in climate diagnostic studies with the aim of understanding the mechanisms and causes of climatic fluctuations. They have derived the sensitivity of tropical free air temperature changes to changes in sea surface temperature patterns and stratospheric volcanic aerosol. The period before a major volcanic eruption yields sensitivities different from the period after the eruption. The equatorial Pacific is particularly important in governing subsequent tropical air temperature. Monthly mean temperature forecasts are being prepared by Dr. Alfredo Navato on an experimental basis in winter from pressure values and monthly sea-surface temperature patterns which are now received close to the end of the month. Coupling these results with a better theoretical and practical understanding of the factors controlling climatic anomalies will permit us to make a realistic assessment of the prospects for climatic forecasting. Studies are also being made of the seasonal cycle, and of the biennial oscillation and Southern Oscillation in relation to global sea-surface temperatures.

Professor Passarelli is conducting a study of snow growth, using laser imagery probes aboard the C-130 aircraft of the Air Force Geophysics Laboratory, to measure the size distribution of ice particles. To approximate the ideal but unattainable process of sampling the same particles at a succession of times, he has developed a flight plan which essentially follows a region of snow. The aircraft flies a spiral which is permitted to drift with the wind, and descends at a rate comparable to the ice-particle fallspeeds. Preliminary results indicate that this procedure yields high-quality measurements, which will be analyzed in the light of current theoretical models of snow growth. These studies are to be extended during the coming winter to include the phenomena associated with melting.

Professor Passarelli is also investigating the role of the winter land breeze in the formation of Great Lakes snowstorms. Aircraft and radar data which he previously obtained at the University of Chicago show that the most severe type of storm is due to the low-level confluence of the land breeze with the mean large-scale flow.

Under the direction of Professor Passarelli and Professor Frederick Sanders, the Department's Weather Radar Laboratory is initiating a dual-Doppler radar study of precipitation bands in New England winter storms. A single Doppler radar measures only one component of the wind field. Two Doppler radars can measure the three-dimensional wind field over areas of order 10^4 km^2 . One of our radars is currently being converted to a Doppler system. The other Doppler radar will be at the Air Force Geophysics Laboratory located 33 kilometers northwest of the MIT campus -- an ideal distance for dual-Doppler work. Even though these precipitation bands produce our heavy winter precipitation, it is still not known why they form.

The Weather Radar Group is involved in an analysis of radar data collected during MONEX (The Monsoon Experiment). This work is being supervised by Research Engineer Spiros Geotis. An unexpected finding is that land and sea breezes seem to play an important role in organizing convective storms along the coast of Borneo. The pattern of radar echo undergoes very regular diurnal changes which seem to reflect the transition from sea breeze to land breeze.

Professor Ronald Prinn and his collaborators have continued work with a 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 to replace an older version of this model, which is presently being used to study transport mechanisms in the stratosphere. Other results have included a self-consistent description of the global ozone budget, a definition of the scales and phase relationships involved in eddy transport of ozone, and a study of the possible role of deserts as sinks for fluorocarbons. Professor Prinn is continuing his involvement in the Fluorocarbon Atmospheric Lifetime Experiment which comprises five globally distributed automated ground stations (in Ireland, Oregon, Barbados, Samoa, and Tasmania) which are taking roughly four-hourly measurements of CFC_1_3 , CF_2Cl_2 , CH_3CCl_3 , CCl_4 , and N_2O . All these species decompose in the stratosphere, leading to ozone destruction. Measurements have been taken for two full years and will continue for at least two more years. The principal aim is to determine the atmospheric lifetimes of CFC_1_3 and CF_2Cl_2 using the measured concentration trends.

In his work on planetary atmospheres, Professor Prinn has constructed a chemical-dynamical model of the Venus atmosphere designed to reveal the distribution of various sulfur compounds as measured by the Pioneer Venus probes. In collaboration with members of the Department of Earth and Planetary Sciences he has been interpreting the wind speed measurements determined from tracking the Pioneer probes, and has been studying the effects of radial mixing on the chemistry of the primitive solar nebula. He has completed his computations of the molecular nitrogen abundance as a function of vertical mixing rates in the deep Jovian atmosphere.

Professor Sanders is investigating organized systems of intense convection in the central United States and elsewhere. Recent case studies have examined the mechanisms of interaction between convection and atmospheric gravity-wave activity as well as the ways in which such systems produce large amounts of rain without reaching the extensive water-vapor saturation characteristic of cyclonic storms. Studies of similar type will utilize the superior data sets acquired during the 1979 SESAME experiment in the central plains. The SESAME and tropical GATE data are being used in conjunction with cumulus cloud models to discover effective means of parameterizing the bulk effects of the convection over large areas.

He is further engaged in a study of sudden development of extratropical oceanic storms, which often reach hurricane intensity during the latter half of the year. Research to date has disclosed that the frequency of occurrence of this event is tied to the presence of strong horizontal gradients of sea-surface temperature especially in the Atlantic. Satellite imagery indicates the presence of deep convective clouds in these storms, as in tropical storms. It is found that current operational numerical prediction models fail to predict the degree of intensification, probably because of an inadequate representation of physical process.

A newly completed study of the development of summertime cyclones at the head of the Bay of Bengal has disclosed that these disturbances are a response to the westward passage of a weak perturbation across Southeast Asia, sometimes from an origin over the South China Sea or eastward, but on other occasions originating over land. A diagnostic study of the dynamics of a singularly well observed example of this type of storm during the MONEX experiment of July has just been undertaken.

Professor Peter Stone has continued to collaborate with NASA's Goddard Institute for Space Studies (GISS) on climate research and studies of planetary atmospheres. They are developing a hierarchy of climate models ranging from the simplest one-dimensional energy balance models to an efficient three-dimensional general circulation model, and are using these models to evaluate the climate effects of increased concentrations of carbon dioxide, changes in the solar constant, and other influences. Professor Stone is a co-investigator on a photopolarimeter experiment which has been gathering data on the Venus atmosphere from the Pioneer Venus Orbiter, and also on a photopolarimeter/radiometer experiment for Project Galileo, the Jupiter-probe-orbiter mission to be launched in 1984.

In his individual work Professor Stone has continued to investigate atmospheric-eddy heat fluxes, using both theoretical and observational studies to try to pinpoint the factors which control these fluxes. He has been directing student research on the development of simple one-, two-, and three-dimensional climate models, the effect of the earth's curvature on baroclinic stability, the transport of heat and momentum by baroclinic eddies, the extension of conventional terrestrial dynamical models to conditions appropriate for Jupiter, and the analysis of mechanisms for producing the four-day circulations on Venus.

EDWARD N. LORENZ

Department of Nutrition and Food Science

During the 1979-80 academic year, the Department continued to be active in graduate and undergraduate educational programs, and productive in research. Specific research programs and accomplishments of individual faculty members of the Department are described in the publication *Faculty Research Summaries*, which is available in the departmental headquarters office.

EDUCATIONAL ACTIVITIES

Graduate Degree Programs

During the 1979-80 academic year, each of the five graduate degree programs offered by the Department underwent a thorough review. In the process of review for each program, a redefinition of purpose and revision of content emerged to reflect current departmental goals and objectives.

The restructured programs are: metabolism and human nutrition, food science, biochemical engineering, toxicology, and neural and endocrine regulation. A total of 175 regular graduate students were enrolled as degree candidates during the 1979-80 academic year, distributed

among these programs in generally the same proportions as in the past year. Master of Science degrees were awarded to 26 students and 23 received doctoral degrees.

Undergraduate Programs

Enrollment in the undergraduate curriculum in Applied Biology (Course VII-B) in 1979-80 was 45, distributed among 20 seniors, 12 juniors, and 13 sophomores. After having remained relatively constant for several years, the decreased number of students in this program reflects the decline in enrollment being experienced by other departments in the School of Science.

Faculty and staff members have continued to participate actively in several facets of other undergraduate programs at the Institute. Currently, the Department provides a total of 15 freshman advisors from among its faculty, technical and administrative staffs, and graduate students. During the academic year, a total of 148 students were enrolled as UROP participants in the Department (65 in the fall term, and 83 in the spring). In addition, 40 students were engaged in full-time research in the Department during the summer of 1980. Support for 37 students was provided by UROP and faculty research funds. Members of the departmental faculty also offered eight undergraduate seminars and acted as premedical advisors for 23 undergraduate students.

Conferences and Summer Courses

The Seventeenth Annual Underwood-Prescott Memorial Symposium was held on September 25, 1979 to honor the awardee, Dr. William J. Darby, in recognition of his contributions to nutrition and food protection for the well-being of the peoples of the world. Dr. Darby presented the memorial lecture which was entitled "The Nature of Benefits."

An eight-week intensive course, "Principles of Toxicology," was offered in the summer of 1980 under departmental auspices. The course, which had the purpose of providing an intensive review of the field of toxicology for scientists entering the field or employed by regulatory agencies and industries, was supported by a training grant from the US Environmental Protection Agency and attended by 31 trainees. The course was organized by a committee appointed by Provost Walter A. Rosenblith and chaired by Dean Robert A. Alberty. Participating faculty included Professors Gerald Wogan, Henri Brunengraber, Michael Marletta, Paul Newberne, Steven Tannenbaum, and William Thilly of this Department; Professors Christopher Walsh, Klaus Biemann, and David Hume of Chemistry; William Deen of Chemical Engineering; Professors Maurice Fox and Graham Walker of the Biology Department and Dr. Ashford of the Center for Policy Alternatives; and also Professors K. Rothman, M. Landy, R. Monson, M. Roberts and S. Thomas of the Harvard School of Public Health, and Professor P. Dews from Harvard Medical School.

FACULTY

New additions to the faculty included the appointment of Dr. Michael A. Marletta who was appointed January 1, 1980 as Assistant Professor of Toxicology. Dr. Noel Solomons was promoted to Associate Professor of Clinical Nutrition and Dr. Cho Kyun Rha was promoted to a tenured position as Associate Professor of Food Process Engineering.

Dr. Nicholas Catsimpoalas left the Institute to become Professor of Biochemistry at the Boston University Medical Center and Professor Hamish N. Munro is now Adjunct Professor of Physiological Chemistry, having accepted the position as Director of the Human Nutrition Center of Tufts/New England Medical Center.

Faculty Awards

Dr. Tannenbaum was the recipient of the 1980 Babcock Hart Award by the Institute of Food Technologists; Dr. John D. Fernstrom received the Mead Johnson Award of the American Institute of Nutrition for his research in nutrition and Dr. Wogan was named the Underwood Prescott Professor of Nutrition and Food Science.

GERALD N. WOGAN

Department of Physics

GENERAL

The Physics Department remained essentially constant in size, with a total of 90 faculty, 262 graduate students, and 259 undergraduate physics majors. Degrees awarded during the year number 24 Ph.D., 12 S.M., and 72 S.B.

Another in our series of all-day symposia focusing on major areas of research in the Department was held; this one on astrophysics. This symposium entitled, "Sun, Stars, and Cosmos," was organized by Professor Bernard F. Burke. Speakers included Professors John Belcher, Burke, Claude Canizares, James Elliot, Philip Morrison, Philip Myers, Stanislaw Olbert, Saul Rappaport, and Rainer Weiss.

The educational program of the Department did not undergo any major changes during the year, but the Undergraduate Education Committee reviewed the subjects taken by physics majors and made recommendations which, if implemented, will strengthen the atomic and quantum physics component in the basic program required of all our majors.

The Undergraduate Physics Colloquium series, presented each week in the Undergraduate Common Room, has continued to be very successful, and provides an excellent informal link between students and the faculty members who describe their research at these meetings.

Our Industrial Program described in last year's Report is being continued. This year we have placed a number of students with eight industrial firms for the coming summer.

The following faculty members received promotions during the year: Associate Professor David E. Pritchard was promoted to Professor. Associate Professors Canizares, Marc Kastner, and Toyochi Tanaka were granted tenure. Assistant Professor Edward L. Wright was promoted to Associate Professor.

Visiting faculty during the year included Daniel Greenberger, visiting professor, and Anton Aharony, Frieder Lenz, Francois Vannucci, and Albert H. Walenta, visiting associate professors.

Leaves of absence during the year included Kenneth A. Johnson, Earle L. Lomon, and John W. Negele, academic year; Kerson Huang and Philip Myers, fall term; Roman W. Jackiw, Malcolm W.P. Strandberg, and Clifford G. Shull, spring term.

New appointments included Thomas Antonsen, Jr., James G. Branson, and Shimon Levit, assistant professors, T. William Donnelly, senior research scientist.

Resigning during the year was Associate Professor Susan G. Kleinmann.

Professor Francis E. Low was named MIT Provost, to be effective July 1, 1980; Professor Jerome I. Friedman was named to succeed him as director of the Laboratory for Nuclear Science. Professor Friedman was also elected as a Fellow of The American Academy of Arts and Sciences.

I am happy to report that Victor F. Weisskopf, Institute Professor, Emeritus, was awarded the National Medal of Science.

Professor George Clark was chosen by the Marshall Space Flight Center to receive the Exceptional Scientific Achievement Award in recognition of his contributions to the Einstein Observatory, HEAO-2. Also, Professor Clark was elected to membership in the National Academy of Sciences.

Professor Paul Joss was selected by the American Astronomical Society to receive the Helen B. Warner prize, particularly for his work on X-ray stars.

Professor K. Uno Ingard was elected to membership in The National Academy of Engineering.

RESEARCH

Astrophysics

The double quasar 0957+561 appears to be the first example of the gravitational lens effect on a large scale. The first detailed radio images of the object were made, using the Very Large Array (VLA) of the National Radio Astronomy Observatory. From optical observations made by colleagues at the University of Arizona, and the Hale Observatories, the two quasar images seem to be the light coming from a single distant quasar, split into two images by the gravitational fields of a massive foreground galaxy and an associated cluster of galaxies. The radio observations show far more detail than the optical pictures, and rule out most of the candidate models. The evidence is overwhelming that, as long suspected from indirect evidence, there is a large amount of "hidden mass" associated with the cluster of galaxies -- perhaps 100 times as much mass as the visible galaxies.

Radio spectroscopic studies of molecules in dense, dark interstellar clouds have measured densities, temperatures, and dynamics that bear on problems of star formation. Some of the clouds seem to be contracting, but more slowly than the free-fall time. Since the clouds have about the same mass as the sun, they appear to be destined to form stars within the next million years or so.

The Cosmic Background Explorer Satellite (COBE), scheduled for launch in 1986, will include an MIT-designed spectrometer in its complement of instruments. The mission is designed to study the characteristics of the cosmic microwave background, the relict radiation from the "Big Bang."

A search for large-scale anisotropies in the sub-millimeter background radiation has been successful. The data from balloon-borne radiometers was correlated with far infrared sky surveys made elsewhere, and the small-scale fluctuations caused by emission from interstellar dust were successfully removed. The resulting dipole anisotropy agrees in magnitude and direction with the effect seen at lower frequencies.

The orbiting Einstein X-Ray Observatory, launched in November 1978 and operated by a consortium of four institutions which includes MIT, continued to be the principal source of new information about the X-ray emission of galactic and extragalactic objects. Most of the time allocated to MIT investigators has been used in the study of the spectra of X-ray sources using the high resolution Bragg reflection spectrometer developed at MIT specifically for the observatory. The X-ray spectra of supernova remnants and of the hot gaseous halos of certain galaxies have proved, as expected, to be rich in emission lines. Accurate measurement of these lines with the MIT spectrometer have yielded new knowledge about the ionic composition and physical conditions in several of the brightest of these sources. Extensive use also has been made of the image recording capability of the Einstein telescope in the study of such diverse topics as the X-ray emission of high velocity OB stars, the structure of supernova remnants, the distribution of faint X-ray stars in globular clusters, the X-ray sources in nearby spiral galaxies, and the nature of X-ray galaxies in poor clusters.

Worldwide observations of X-ray burst sources were carried out using the Japanese satellite, Hakucho, combined with ground-based optical and infrared observations by astronomers of various countries. A unique series of 15 optical bursts from MXB 1636-53 were detected in the summer of 1979 by observers at the European Southern Observatory (in Chile), with five of these being detected simultaneously by Hakucho. The data have contributed substantially to our knowledge of the geometry of the accretion disk surrounding the compact neutron star (the X-ray emitter). Further multi-color optical and X-ray observations were carried out that should give proof that the temperature of the accretion disk during an X-ray burst is about 50,000 to 100,000 K, as suspected.

Optical observations are carried out in the North at the McGraw-Hill Observatory (operated jointly by the University of Michigan, MIT, and Dartmouth College), and in the South at Cerro Tololo Observatory in Chile. This year two new focal-plane instruments have been put into operation at the McGraw-Hill Observatory: a grism (grating and prism) with an image tube for obtaining spectra of many faint objects simultaneously, and a slit-scanning photometer for studying crowded star fields. Also, a CCD imager/spectrometer system, which uses an advanced Texas Instruments array, will be evaluated on the telescope this fall. A major area of research is the study of binary systems containing highly condensed stars formed at the end of stellar evolution: white dwarfs, neutron stars, and black holes. The phenomena of these systems are extremely rich and varied as illustrated in the case of two systems studied this year: an X-ray/optical pulsar with 7-second periodic pulsations, 1,000 second quasi-periodic flares, and a miniature "normal" star companion of less than a tenth of a solar mass; and an X-ray nova which brightens for several weeks, emits intense bursts of X rays, and whose transient optical counterpart was discovered and studied. Another major program is the discovery and study of X-ray active quasars and galaxies in coordination with work on the Einstein Observatory. A dozen objects are being studied for clues to the nature of the energetic phenomena which drive them.

The outermost hydrogen-burning shell of a neutron star should have a significant effect upon the properties of thermonuclear flashes (though the hydrogen-burning shell cannot flash by itself).

A significantly improved computer code now shows that hydrogen burning in neutron-star surface layers occurs under conditions of extraordinarily high density and temperature ($\rho \sim 10^6 \text{ g cm}^{-3}$ and $T \sim 10^9 \text{ K}$). The detailed study of the effects of the hydrogen-burning shell upon the character of thermonuclear processes in neutron-star envelopes can now be carried out without the expenditure of excessive computer time.

It is possible that a thermonuclear flash deep within the surface layers of a neutron star can, under some circumstances, precipitate dynamical phenomena near the neutron-star photosphere. Such phenomena may be related to the complex temporal structure of X-ray bursts near the time of peak luminosity and to the "precursors" that are seen in the fast X-ray transients. It is even possible that a phenomenon of this type resulted in the spectacular γ -ray burst of March 5, 1979. A hydrodynamic code has been added to present computer codes to investigate these possibilities quantitatively.

Atomic, Plasma, and Condensed Matter Physics

The Physics Department has nine experimentalists and two theorists whose objective is to study and understand the properties of the condensed states of matter. Their research involves such diverse states of matter as quantum fluids, liquid crystals, and two-dimensional states on surfaces as well as more conventional solids. The past year has been a successful one in the program to produce a fluid phase of spin-aligned atomic hydrogen. In this system there has been an interesting new state of matter predicted to result from Bose-Einstein condensation that should occur through strong quantum effects in the gaseous state. A stable gas at one percent of the required density has been produced, and the necessary increase appears possible. The techniques of preparing cold atomic gases are also important for studies in atomic physics and chemical kinetics.

Significant experimental and theoretical advances have been made in understanding electronic states in glasses. Time dependent optical spectroscopy has been used to measure the electron-phonon interaction which stabilizes the localized states in the band gap, while accurate calculations of defect states in glasses have been carried out using a self-consistent pseudo-potential method. Amorphous semiconductors must be doped in order to fabricate devices; hydrogenation makes doping possible, and calculations have been carried out which explain quantitatively and accurately the role of hydrogenation in silicon. A spectrometer to study experimentally the electronic states in solids by means of electron energy loss scattering spectroscopy is nearing completion.

There has been impressive progress in the experimental investigation of gases adsorbed on graphite substrates. These surface physics experiments are important in understanding two-dimensional melting and structural transitions. Preliminary experiments using synchrotron radiation have provided an order of magnitude resolution improvement over that attainable with conventional laboratory sources. Members of the Department have obtained the necessary funding and are now constructing a spectrometer to use on the National Synchrotron Light Source at Brookhaven when it becomes operational in 1981. With this facility it will be possible to explore a variety of important new physical features connected with surface structures and transitions. The facility will also have important impact on other research in the Department.

On the theoretical side, renormalization group calculations incorporating realistic interactions, defects, and finite size effects have apparently resolved previous disagreement between theory and experiment for two-dimensional adsorbed gases on graphite. Theoretical work also suggests that systems (such as spin glasses) with residual entropy at 0°K may have algebraic decay of correlation functions -- an important result if generally true. Calculations also have been carried out for the energy of core excitons at solid surfaces, and the results agree well with experimental measurements on gallium arsenide.

Liquid crystals offer a rich variety of phases of interest to those studying condensed states of matter. Recent experiments have shown that the algebraic decay of correlation functions, theoretically predicted for two-dimensional solids, can be observed in the three-dimensional smectic A phase. Another recent result is that the smectic B phase of some materials is, in fact, not a liquid crystal phase, but possesses three-dimensional long-range crystalline order. There are also materials which are interesting to study from the fundamental viewpoint of statistical mechanics and have important biological functions. These include micelles (aggregates of surface active molecules) and gel phases of polymer solutions. Interesting results have been obtained on the formation of micelles as well as cluster formation in the early stages of gelation. Phase transitions in gels which are analogous to critical phenomena in fluids have been studied; as well as explaining many phenomena previously observed in gels, these results may have important practical applications.

In the area of biological physics, inquiry into the physics of cataract formation continues. The development of a molecule microscope to characterize the surfaces of biological materials is also continuing. A thermodynamic model of nervous impulse conduction, which explains the existing data as well as the classical Hodgkin-Huxley model, has been put forth. Experiments to see if it provides the correct physical insight are necessary.

Five members of the Department faculty have experimental interests in atomic physics, molecular physics, or quantum electronics. Experiments on highly excited Rydberg atoms in a magnetic field (where the magnetic interactions dominate electrostatic effects) have revealed a new approximate symmetry which can also be calculated numerically but is not yet fundamentally understood. These results are important to advances in astrophysics where matter often exists under conditions of extreme magnetic fields. Recent optical pumping experiments using laser sources in combination with velocity-changing collisions have made efficient polarization of ground state alkali vapor atoms possible by effectively pumping atoms over the entire Doppler-broadened spectrum. Laser-induced nuclear orientation has been used to demonstrate the measurement of the isomer shift and the g factor for an excited nuclear state of ^{24}Na . Experiments on rotationally inelastic collisions between atoms and molecules have shown the angular momentum transfer to be zero for scattering angles less than a critical value, thus producing a "halo" in the cross section for this process. Scaling laws, used to predict the cross section for a wide variety of processes from the known values for a few, have been experimentally verified. The National Science Foundation has granted \$1.5 million over the next four years to establish a regional laser center at MIT (for details see the report of the Spectroscopy Laboratory). This will be of benefit for programs in the Department.

Studies of four-photon mixing in germanium are continuing. This may provide an efficient way to produce tunable infrared radiation. Recent calculations suggest a method to achieve semiconductor lasers with wavelengths greater than 30μ and an experimental test is planned.

In plasma physics (which involves five members of the Division) the Versator II tokamak (major radius = 45 cm; toroidal field = 15 kilogauss) has operated reliably during the past year, producing high-quality plasma discharges with moderate temperatures (400 - 600 eV) and densities ($1 - 4 \times 10^{13} \text{ cm}^{-3}$). Plasma heating and RF current-drive experiments have begun at the lower hybrid frequency (800 MHz), and electron cyclotron resonance heating experiments on Versator II will soon be initiated using the 36 GHz gyrotron developed by the Naval Research Laboratory.

The Alcator C tokamak (major radius = 64 cm) has operated extensively at intermediate magnetic fields (toroidal field = 60 kilogauss with densities in the $1 - 3 \times 10^{14} \text{ cm}^{-3}$ range and electron temperatures up to 1.5 keV. The toroidal magnet and electrical systems have been tested at fields in excess of 100 kilogauss, and plasma experiments have begun at toroidal fields of 90 kilogauss. During the past year, the klystron and waveguide window development has been completed for the high-power (4 MW, 4.6 GHz) lower hybrid heating experiments planned on Alcator C. Initial heating experiments will begin in the second half of 1980.

Plasma theory investigations have continued in several areas including: basic studies of the macroscopic equilibrium and stability properties of high-temperature fusion plasmas, microstability behavior and associated anomalous transport, alpha-particle induced microstability behavior, basic theoretical studies of the influence of collective effects on the free electron laser instability, and the influence of self fields on the equilibrium and stability properties of heavy ion beams.

CENTER FOR THEORETICAL PHYSICS

Particle Theory

It is now believed that the correct theory of the strong interactions is quantum chromodynamics (QCD). There is a large class of theoretical predictions, using perturbation theory, which should be accurate at very high energies where the distances explored are very short and the QCD interactions become weak because of the asymptotic freedom of the theory. These asymptotic predictions do not depend upon a knowledge of how hadrons are built out of the basic quarks and gluons of QCD. However, to confront these predictions with experiment, even at the highest energies presently available, requires estimation of corrections which do depend upon hadronic structure, for which perturbation theory cannot be used. We know that the 'MIT bag' model of confined quarks and gluons expresses many necessary features of hadronic structure, and one of the main themes of our research has been to use the model, to evaluate realistically the consequences of the more fundamental QCD theory. Similarly, many consequences of the now firmly established Weinberg-Salam theory of the electromagnetic and weak interactions, and of the more speculative grand unified theories of all three interactions, require details of hadronic structure for their correct interpretation. We have used the bag model for this purpose, with many interesting results.

Another theme has been the deeper interpretation of the bag model in the light of QCD. This has led us to a successful analysis of low-energy hadron scattering in terms of multi-quark bag states, and to a promising reconciliation of the various apparently contradictory ways of putting the pion in the theory.

The problem of directly deducing a successful theory of confined quarks and gluons from QCD is still unsolved. We have been using the simplifications which would arise if the number of 'colors' was large as a starting point in several approaches to this problem. There is reason to think that the real number, three, counts as 'large' since many of the qualitative features of this limit do correspond to features of the real world.

The investigation of the properties of classical gauge field theories continues to be a major theme of our research. In addition to much analytical work on the solutions of these nonlinear equations under various symmetry restrictions, and to a general examination of the symmetry properties, numerical exploration of interesting solutions is being carried out.

Nuclear Theory

The Nuclear Theory Group is engaged in a wide variety of continuing programs in nuclear structure and nuclear reaction studies. These range from the underlying description of nuclear physics in the language of quarks and gluons, through work involving mesons and isobars in nuclei, to studies of complex multinucleon systems colliding in heavy-ion reactions. The full range of energies is spanned, from very low energy neutrino, to the border with high-energy physics.

Electromagnetic and weak interactions in nuclei: Work on electron scattering is proceeding on many fronts, including nuclear configuration studies, valence nucleon distribution determinations, studies of collective modes, sum rules in quasielastic scattering, single-particle momentum distributions, meson exchange current effects, and pion production. Various aspects of the weak interaction are likewise under investigation including in particular studies of the neutral weak interaction in nuclei as seen in neutrino scattering.

Mesons and nuclei: The roles of pion and isobar degrees of freedom are being studied in several contexts and in particular the suitability of the isobar-doorway approach for a wide class of many-body scattering problems is being investigated. The variety of topics under study includes the pion-nucleus optical potentials, πN Bremsstrahlung, corepolarization effects in pion-nucleus scattering, dynamic nuclear polarization in pion atoms, and others. Another topic involving pions in nuclei is a study of pion condensation in high-energy heavy-ion collisions where there is a possibility that such effects may be seen at nucleon densities dramatically lower than in equilibrated matter. Still another direction being followed which falls under this general heading is work on kaon-nucleus interactions in nuclei. In particular the $\Lambda(1520)$ region is of great interest as it involves an especially narrow resonance. An isobar model with the $\Lambda(1520)$ replacing the $\Delta(1232)$ is being constructed and will be applied to (κ, κ') and (κ, π) reactions.

Quantum chromodynamics and nuclear physics: A variety of projects are actively being pursued involving a QCD description of hadrons and the forces between them within the context of the MIT bag model. The ultimate aim of this study is to understand nuclear physics in these more fundamental terms. Several studies are in progress including a study of heavy quark-antiquark pairs, solutions of the quark-gluon problem in an axisymmetrically deformed bag, studies of the energetics and decay models of massive multi-quark states having high strangeness and charge to baryon number ratios, and radiative decays of strange resonances.

Nuclear reactions: Research is continuing on studies of the statistical multi-step direct reaction mechanism, in particular as applied to heavy-ion reactions in the deep inelastic region. Other work is proceeding on studies of elastic and inelastic scattering of high energy hadrons by nuclei with emphasis on the spin-spin inter-nucleon interaction.

Nuclear models: A large class of nuclear model investigations is under consideration including: 1) Mean field theory studies of large amplitude collective motion and spontaneous decay employing the stationary phase approximation of the many-body evolution operator. 2) Generator coordinate methods and related techniques where the damping of collective motion by energy transfer to intrinsic modes of excitation is being incorporated, with attention paid to the conditions under which this effect may be described as "friction." Further work is being done employing the Born-Oppenheimer approximation to describe large scale collective dynamics as encountered in fission and heavy-ion collisions. 3) Collective models such as the random phase approximation and improvements beyond it, the isoscalar monopole mode, particle-rotor models, and descriptions of nuclear rotation and its effects on beta and gamma deformations. 4) Studies of nuclear matter within the context of a model relativistic quantum field theory.

Mathematical methods: Various projects are being investigated which fall under this general heading and include a study of the possibility of doing numerical calculations in elementary quantum mechanics using Feynman path integral techniques.

Experimental Nuclear and Particle Physics

High energy physics at MIT continues to be based upon the activities of three groups -- the Accelerator Physics Collaboration (APC), the Counter-Spark Chamber (CSC) group and the Electromagnetic Interactions (EMI) group. Each of these is at present involved in one or more major experimental programs at high energy accelerators in Europe and the USA.

The main current activity of the APC group involves a study of the decays of "charmed" mesons produced by polarized photons in the 20 GeV beam of the Stanford Linear Accelerator. The detector involves a 40-inch bubble chamber coupled to a hybrid spectrometer system, capable of observing both charged and neutral decay products, patterned after the hybrid system developed for use at the Fermilab (and described in last year's report). Aside from the elucidation of the details of the photoproduction of charmed mesons, and their decay properties, it is anticipated that the use of polarized photons will permit the determination of the spins and parities of the charmed mesons produced by them.

At the Fermilab, where the aforementioned hybrid bubble chamber-counter system was first developed and installed, it is planned to use this system, which has been greatly improved and augmented by an effective neutral particle spectrometer "CRISIS," developed at MIT -- to study the quark- and gluon-induced jets produced by 200 GeV pions, kaons, and protons. In particular, the various vector mesons produced will be used as indicators of the nature of fundamental processes leading to jet formation. Owing to the possibility of inserting plates of different atomic number into the bubble chamber of the hybrid spectrometer system, it should also be possible, via the A-dependence of various parameters of the interactions studied, to draw significant conclusions on quark and gluon interactions in nuclear matter.

The major effort of our CSC group has been in the design, construction, and testing of a detection and analysis system for neutrinos produced at the Fermilab. In particular, this experiment is designed to study the properties of the neutral currents involved in the weak interactions. The spectrometer is now constructed, and the testing, debugging, and calibration of this instrument is now in process. The CSC group also has devoted a considerable effort during this past year to the conclusion of the analysis and the preparation of publications, summarizing the results of its extensive spectrometric study of the inclusive production of a variety of particles from targets of protons and of complex nuclei.

The last year has been a very productive one for the Electromagnetic Interaction group. This is primarily due to the electron-positron storage ring, PETRA, coming into full operation at center of mass energies up to 36 billion electron volts. Our experiment, known as MARK J, has been taking data during the entire year and has produced a number of important physics results. Primary among these is the discovery of 3-jet events which show that particles known as gluons are produced in e^+e^- interactions. Gluons are the fundamental carriers of the strong interaction which binds quarks together to make protons and neutrons. The currently favored theory of the strong interactions, quantum chromodynamics, predicts that gluons will be radiated when quark antiquark pairs are produced. The final state then has two quarks and a gluon and these three primary particles produce the three jets which we detect. We have used these events to measure the strong interaction coupling constant α_s in a very clean way. This is one of the fundamental constants of nature and our continued work on this subject will be of great importance in the next year. In addition to these QCD-related measurements, we have searched for the expected new quark known as "top" and have shown that if it exists its mass must be greater than 17 GeV. This puts constraints on theories which unify the strong, weak, and electromagnetic interactions. We have shown that the leptons e , μ , and τ and the quarks behave like simple, pointlike particles down to distances of 2×10^{-16} cm (about one thousandth of the size of the neutron or proton) -- a significant improvement over previous limits.

Our experiment at CERN intersecting storage rings has been completed recently. It has produced high statistics results on J and upsilon production, on Drell-Yan production of muon pairs in previously unexplored regions, and on QCD processes associated with the Drell-Yan mechanism.

In the nuclear area, the major MIT effort is centered at the Bates Linear Accelerator. Since Bates has in recent years evolved into a truly national facility for the use of intermediate energy electrons (up to 400 MeV) for nuclear structure studies, it would be difficult to summarize the Bates program short of a comprehensive survey of the nation's efforts in intermediate energy nuclear physics via electromagnetic probes. In what follows, we give a very brief survey of the major MIT contributions to this program.

Our unique contribution has been in the construction and operation of the Bates Linac as a major national facility. In the past year, a new experimental area has been constructed and brought into operation which, together with continuing improvements in the reliability of the accelerator and the support facilities provided to outside user groups, has attracted scientists from 29 outside institutions, including a number from Canada and Europe. The major MIT programs continue to center on electron-scattering studies using the Bates high-precision scattering spectrometer. In addition, significant studies of electroproduction of protons and pions are being carried out, all with the view of unravelling the basic aspects of the structure of nucleons and their interactions within atomic nuclei.

An extensive program of facility development is in progress: two large-solid-angle spectrometers for pion and proton detection are under construction in the new experimental area; a polarized electron source for studies of parity violation is under construction in a Yale-MIT-Harvard collaboration; a beam-sharing system to improve operational efficiency is being developed; \$1.8 million was provided in fiscal year 1980 for a project to increase the beam energy to about 700 MeV by means of a magnet system which will allow a second pass of the beam through the accelerator -- the recirculator. Work on all these projects is well advanced, and we expect their completion over the next year and a half -- with the recirculator projected to become operational in late 1981 or early 1982.

During this past year, studies also have been carried out on the design problems for the next steps in electron accelerators for nuclear research. In particular, we have reviewed possible designs of a 2 GeV, continuous-duty electron accelerator as a next stage in the development of the Bates Laboratory. Some unique design features for a continuous, multiple, ambient temperature isochronous channel linac are now under study.

The remainder of our nuclear research efforts have been concerned with heavy-ion interactions, studying the structure and dynamics of nuclear systems at high angular momentum and excitation energy. The experimental program has been primarily carried out at the Double Tandem Van de Graaff facility at Brookhaven National Laboratory, as well as at the Lawrence Berkeley Laboratory. At Brookhaven, the Heavy-Ion Group has designed and installed a Recoil Velocity Selector (RVS) for separating and studying heavy-ion fusion recoils from the beam at 0° ; this facility, greatly improved during this year, is unique to the US. A similar device is now being constructed by the group for installation at the Holifield Heavy-Ion facility at Oak Ridge, and our program will be shifting there as beams become available at this premier facility in late 1980.

In lighter nuclear systems, particularly the $^{12}\text{C} + ^{12}\text{C}$ system, considerable study of "quasi-molecular" states has been undertaken. Here, the MIT group has made major contributions to understanding these high angular momentum resonances in a dinuclear system. With the RVS a systematic program to understand the fusion mechanism is under way, and measurements at the microbarn cross-section level can be made. Fission is the major decay mode of very high angular momentum states, and the angular momentum disposal to the fission fragments is being studied using a large hodoscope of gamma ray detectors. This provides information on how the nucleus carries angular momentum, whether by collective rotation or independent particle motion.

As noted in last year's Report, a scanning heavy ion microscope (SHIM) has been developed, capable of detecting and identifying trace elements in various materials. Most recently, this new and versatile instrument has been directed into the study of various solid-state devices, especially those involving photovoltaic applications. A number of interesting industrial applications have already emerged.

HERMAN FESHBACH

Interdisciplinary Science Program

The Interdisciplinary Science Program (Course XXV) is sponsored by the School of Science with the intent to provide special opportunities for graduate and undergraduate students interested in science programs that differ significantly from established departmental offerings. For example, students may concentrate in fields such as astronomy, meteorology, oceanography, human cognition and artificial intelligence, perceptual systems, medical sciences, and environmental sciences. Students in the program arrange their own curricula in consultation with faculty advisors, subject to the approval of a faculty committee consisting of representatives from the Department of Psychology and all departments in the School of Science.

Two degrees are offered under the auspices of the Interdisciplinary Science Program, the Bachelor of Science and the Master of Science in Interdisciplinary Science. The objective of the latter program is to provide an opportunity for graduate study in an interdisciplinary area with a strong science core. Students gain preparation for positions in industry, government, research, education, and medicine where training beyond a bachelor's degree is required. They may choose to follow one of the specified degree options, or design their own program. The guidelines and requirements for each specified curriculum are predetermined by a special faculty committee whose members have expertise in that area. Specified master's programs are currently being offered in Animal Cell and Tissue Culture Science, Environmental Chemistry, Science Communication, and Science Education.

The Science Communication degree option is now a year old; response to this program has been enthusiastic. Four students are currently enrolled, and six more are expected to begin in September 1980. The areas of science concentration chosen by these students are: psychobiology, genetics, medical biology, physiology, physics, energy efficiency in architecture, aquatic ecology, and toxicology. Courses are also taken in developing film and writing communication skills, and the social and public policy aspects of science and technology. A search for comprehensive funding has been initiated in order to ensure the continuation of this urgently needed program.

The Interdisciplinary Science Master's program received initial approval in spring 1975 as a three-year experiment. Subsequently, in spring 1977, approval was given to extend the experiment an additional three years. A report summarizing the activities of the program and its students since its beginning is now being compiled, and will be discussed as the program is considered for permanent status. The statistics summarized below are an indication of the numbers of students in the program, the concentrations they have chosen, and the students' academic records during the initial three years and during the past two years.

Thirty-five Master's students have graduated from the Interdisciplinary Science Program so far, and 13 are currently enrolled in the program. Nine are expected to begin Course XXV in September 1980.

In the designated programs 11 students have chosen the option in Animal Cell Science, seven in Environmental Chemistry, 10 in Science Communication, and six in Science Education. Individually designed programs fall into the following categories: 11 in Biomedical Science, three in Medical Engineering, four in Psychology and Artificial Intelligence, one each in Analytical Biochemistry, Space Sciences, Mathematical Modeling, and Microclimate for Architecture.

Cumulative grades for the initial three years of the program ranged from 3.6 to 5.0; the median was 4.7. During the academic year 1978-79 the grades ranged from 3.9 to 5.0; the median was 4.5. During the past academic year cumulative grades ranged from 3.5 to 5.0; the median was 4.3.

During the academic year 1979-80, three students were awarded the Master of Science in Interdisciplinary Science: one in Animal Cell Science, one in Mathematical Modeling, and one in Biomedical Science. The Bachelor of Science was awarded to six students: three in psychology,

Spectroscopy Laboratory

one in biomedical sciences, one in astrospace, one in science education. There were 17 graduate and 12 undergraduate students in the Department during 1979-80. Cumulative grade statistics for the undergraduates are given below.

Seniors' cumulative grades ranged from 3.4 to 4.8; the median was 4.1. Juniors' cumulative grades ranged from 4.3 to 4.9; the median was 4.6. Sophomores' cumulative grades ranged from 3.6 to 4.8; the median was 4.4.

JOHN M. BUCHANAN

Spectroscopy Laboratory

The Spectroscopy Laboratory is engaged in applying the techniques of modern spectroscopy in order to advance our knowledge of the structure and dynamics of atoms and molecules and the properties of liquids and solids. These techniques include the use of lasers and high resolution spectrometers.

An interdepartmental laboratory, the Spectroscopy Laboratory encourages participation and collaboration among members in the various disciplines of science and engineering. This past year there has been participation from several MIT departments including Chemistry, Physics, Biology, Energy Laboratory, Electrical Engineering, and Nutrition and Food Science. Outside collaborations included Harvard Medical School, Boston University, and Wellesley College, as well as other institutions.

MIT Regional Laser Research Center

This past year saw the establishment of the MIT Regional Laser Research Center in the Spectroscopy Laboratory with Professor Michael S. Feld, Department of Physics, as Director. This Center, the result of a National Science Foundation grant, enables academic, industrial, and other qualified users in the northeastern part of the United States to pursue research in broad areas of laser spectroscopy and dynamics, to develop new types of coherent sources and techniques, and to perform diagnostic studies of various substances and materials. Emphasis is given to basic research in far-infrared, infrared, visible, and ultraviolet spectroscopy, photochemistry, ultra-high resolution spectroscopy and dynamics, biophysical spectroscopy (including Raman), and instrumentation.

RESEARCH

Professor Richard C. Lord and Dr. Thomas J. Thamann, Department of Chemistry, continue their laser Raman studies of the structure of biological molecules. Extending their work on chemical and thermal denaturation of the enzyme ribonuclease, they have measured the spectrum at different temperatures of a single crystal prepared by Professor Gregory Petsko, Department of Chemistry, and co-workers. Although such a crystal has been found to lose its x-ray pattern at 58°C, its Raman spectrum varies with temperature in about the same way as found earlier for aqueous ribonuclease.

Professor Alexander Rich, Department of Biology, and his colleagues have recently discovered a left-handed form of the DNA double helix, using a crystal structure analysis. This structure, a significant alternative conformation for DNA, has the novel feature of sequences containing alternating purines and pyrimidines. Five additional structures, containing both four and six base pairs, have now been solved, all with the specialized sequence of alternating guanine and cytosine residues. Two different conformations are possible in the left-handed helical form, with the phosphate group in the GpC sequence either folded towards the helical groove or pointed

away from it. These two conformations are influenced by the presence of magnesium cations in the crystal lattice. Also in progress is a Raman study with Professor Lord of the new DNA heximer.

In another project, Professor Rich and Dr. Andrew Wang, also of Biology, have continued mapping the fine details in the folding of the DNA binding protein from fd bacteriophage. This protein binds single-stranded DNA and is used for opening up the double helix prior to replication. One segment of the molecule has a long concave trough, which strongly suggests that it may be the binding site that holds the extended sugar phosphate backbone of a single-stranded DNA segment. Recently, other crystals have been obtained in which the protein crystallizes together with the oligonucleotides of DNA. These complex crystals are currently under analysis.

Professor Jeffrey I. Steinfeld in collaboration with Drs. Thomas Anderson and Melissa Charron, all of the Department of Chemistry, have determined polarization relaxation times for the $J = 6, 9,$ and 10 Λ -doublet transitions in the 01^1_0 vibrational level of HCN by means of microwave transient emission. Relaxation rates induced by He, H_2 , and CH_3F have also been obtained for the $J = 6^2$ transition. The dephasing cross sections for foreign gas collisions are consistent with the force laws operative in each case. The HCN- H_2 result provides a comparison with the recently measured cross-section of the isoelectronic molecular ion system, HCO^+-H_2 and confirms a prediction that rotational relaxation rates are only moderately faster for molecular ions.

Drs. Donald S. Coe and Brian Haynes of the Energy Laboratory have measured fluorescence excitation and emission spectra of polycyclic aromatic hydrocarbons, such as pyrene and fluoroanthene, in atmospheric flames. Although somewhat broadened, the spectra of different species retain their individual characteristics. The "hidden" $S_2 \rightarrow S_0$ transition in pyrene, resulting from thermal population of S_2 from S_1 , is quite intense. These spectra will be useful for real-time, in-situ detection of these carcinogens in combustion sources; detection limits of ~ 0.1 ppm for individual species have been achieved.

Professor Ali Javan and his group are using tunable dye laser radiation to excite high lying, chemically reactive vibrational levels in the ground electronic state of the HD molecule. Opto-acoustic and other detection techniques are being used to explore a variety of dynamic and gas kinetic processes. The high resolution of these experiments enables accurate measurement of the 6th, 7th, and 8th HD overtones, from which the anharmonic terms and the shape of the molecular potential function will be determined.

Professor James L. Kinsey, Department of Chemistry, in collaboration with Dr. Charles T. Rettner, also of the Chemistry Department, has studied energy disposal in reactions of the 1D_2 electronic state of atomic oxygen, and important upper atmospheric species. The distributions on internal states of the OH product from the reaction $0(^1D_2) + NH_3 \rightarrow OH(v+N) + NH_2$ have been examined by laser-induced fluorescence. The excited oxygen was produced by flash photolysis of ozone by a frequency quadrupled Nd:YAG laser. A bimodal rotational-state distribution was observed. The peak at low rotational energies was interpreted as coming from reactions yielding NH_2 in an electronically excited state (2A_2). Support for this interpretation was found in the observation of chemiluminescence in the region of the $^2A_2 \rightarrow X^2B_2$ transition with approximately the correct intensity.

Professor Robert W. Field, Department of Chemistry, is continuing his research on the structure and dynamics of diatomic molecules. A set of laser spectroscopic techniques has been used to perform an extensive study of the electronic structure of the alkaline earth halides. A unified ionic-bonding picture of the hyperfine structure, spin-orbit coupling, Λ -doubling, spin rotation interaction, and Γ/Σ splitting has been constructed for the $A^2\Pi$ and $B^2\Sigma^+$ states of all the MX molecules ($M=Ca, Sr, Ba; X=F, Cl, Br, I$). In addition for BaF and CaF the high excited states have been arranged into nl Rydberg series. The simplicity of the results is striking. This work has been performed in collaboration with Professors Colan Linton of New Brunswick and Visiting Scientist Richard F. Barrows of Oxford.

Professor Field's research on cataloging and characterization of the low-lying electronic states of the rare earth oxides PrO, EuO, CeO, and YbO is nearly completed, leading to simple crystal-field interpretations of the structure, which differs only in the angular momenta associated with nonbonding metal-centered f-electrons. Professor Field's associates in this study are Dr.

Christian Athenour of Nice, France; Dr. Ingemar Renhorn of Stockholm, Sweden; Dr. Jean-Michel Robbe of Lille, France; and Dr. Bernard Pinchemel of Lille, France.

Professors Field and Kinsey, Dr. Carter Kittrell, and Dr. Daniel Katayama of the Air Force Geophysics Laboratory have collaborated on a new laser double-resonance technique, called stimulated emission pumping, for investigating the structure and chemical properties of highly-excited vibrational levels in small polyatomic molecules. This technique is being used to excite the selected vibrational state of I_2 and D_2CO . Another study, in collaboration with Professor Roger Bacis of Lyon, France, involves investigation of energy transfer in $^2\Pi$ and $^2\Sigma^+$ states of polar molecules. A new propensity rule for J-changing collisions has been noted; namely, that the "rotation-independent" e/f parity is conserved. Further experiments are planned to study velocity changes in these collision-induced transitions.

Professor Feld has begun a new set of studies of superradiance, the coherent spontaneous emission of a dense collection of excited atoms or molecules. In one experiment adiabatic rapid passage is being used to create a population inversion in the resonance transition of ytterbium ($\lambda=551$ nm) which, under certain conditions, will result in superradiant emission. This new method of preparation of a superradiant state will greatly expand the possibilities for studying this fundamental phenomenon. A related project, in collaboration with Dr. Farris P. Mattar of New York Polytechnic Institute and Dr. Hyatt Gibbs of Bell Laboratories, is a theoretical analysis of the influence of non-plane wave effects on the shape of the superradiant pulse profile. The results show that transverse effects reduce the ringing predicted by plane wave models, resolving a long-standing controversy and leading to better agreement with experiments.

Professor Feld's laser-induced nuclear orientation experiments have progressed. These experiments study the angular distribution of gamma radiation emitted from an unstable (excited state) nucleus, whose atomic levels have been optically pumped by a monochromatic laser field. Extensive measurements on the isomer ^{24m}Na reveal a large negative nuclear g-factor, the first such negative value found in the sequence of sodium nuclides, and a large (300 ± 125 MHz) isomer shift -- indicative of a significant hyperfine anomaly and/or nuclear deformation in this isomeric state. Others participating in these experiments are Professor Martin Deutsch, Department of Physics, Professor D. Ramachandra Rao of the Spectroscopy Laboratory and Dr. Daniel Murnick of Bell Laboratories.

Another area of interest of Professor Feld's group is optical pumping of alkali vapors using monochromatic laser radiation. Recent work in sodium vapor has demonstrated that complete optical pumping of the entire Doppler profile can be accomplished at low powers using a single mode dye laser by adding trace amounts of buffer gas (~ 0.1 torr). The buffer induces velocity-changing collisions, which rapidly redistribute the atoms across the Doppler profile, and diffusion, which increases the laser-atom interaction time. This effect is a promising method for producing dense spin-polarized vapors for use in nuclear reaction studies, and in other physical applications.

Professor Edward I. Solomon, Department of Chemistry, has continued his research of active sites in metalloenzymes using laser resonance Raman spectroscopy. In a study of structure-function relationships in binuclear copper active sites, it has now been shown that a structural distortion exists between the active sites in arthropod and mollusc hemocyanins. This distortion strongly affects exogenous ligand binding at the binuclear copper site and, most importantly, is responsible for the much lower catalase enzyme activity exhibited by the arthropod phyla. These studies are being extended to the binuclear copper mono-oxygenase tyrosinase. A second area of interest is development of laser resonance Raman probes of the normally spectroscopically inaccessible type 2 copper site in laccase and ceruloplasmin. For these enzymes it is now possible to bind specific probe ligands to the type 2 copper site; this activates low energy ligand-to-metal charge transfer transitions, which can be probed by resonant Raman techniques. This group is pursuing ligand isotope studies as chemical perturbations of the resonance Raman spectrum, and also parallel studies of appropriate small molecule model systems.

In another collaboration, Professor Theodore Ducas of Wellesley College, Professor Henri Brunengraber of the Nutrition and Food Science Department, Dr. Geza Jako of Boston University Medical School, Professor Petsko, and Lawrence W. Ryan, Jr., of the Chemistry Department, are continuing their work in the photoacoustic spectroscopy of biological tissue. Work in the infrared is being expanded to include quantitative measures of thermal conductivities and infrared

absorption spectra. Preliminary studies of characteristic spectral features of different kinds of rat tissue -- liver, cartilage, and muscle -- indicate a difference between the spectra of normal and cancerous tissues. Such information may prove useful in characterizing different forms of tissue and the influence of radiation on the tissue. This is of particular interest due to the use of CO₂ lasers in surgery.

An ongoing study by Professor Samuel A. Latt and Dr. Elhanan Sahar, both of Harvard Medical School, in collaboration with Dr. Stephen Fulghum, Department of Physics, Dr. Kittrell, Department of Chemistry, and Professor Feld, uses laser activation of 8-methoxypsoralen to induce sister chromatid exchanges (SCEs) in Chinese hamster ovary cells, by subjecting cells of DNA to single or multiple pulses from a near UV laser. It has been shown that single light pulses, which produce only 8-methoxypsoralen-DNA monoadducts, are sufficient to induce SCEs, and that crosslinks probably contribute little to SCE induction. Crosslinks do, however, retard cell cycle traverse, as determined by laser-activated fluorescence flow cytometry. The results provide information about the type of DNA damage responsible for SCE induction, and may help guide strategies to minimize mutagenic/carcinogenic side effects of psoralen plus light therapy of psoriasis.

MICHAEL S. FELD

George R. Wallace, Jr. Astrophysical Observatory

The George R. Wallace, Jr. Astrophysical Observatory is a teaching and research observatory, located in Westford, Massachusetts. Its facilities consist of a 24-inch reflecting telescope, a 16-inch reflecting telescope, and a small building that houses a workshop, darkroom, computer, and observers' quarters.

During the past year, Richard Baron, a research engineer, and Douglas Mink, a programmer, joined the Observatory staff.

The past year's research included the observation of a series of lunar occultations of stars in the Hyades cluster by the Observatory staff, Dr. Deane M. Peterson (visiting scientist at MIT, on leave from SUNY, Stony Brook) and Professor James Elliot. Collaborating observations were made at Agassiz Station and Mt. Hopkins Observatory by Dr. R.M. McCrosky and Dr. T.C. Weckes of the Harvard-Smithsonian Center for Astrophysics. Precise angular separations of the binary stars ADS 3248, ϕ 342 and θ ' Tau were obtained, as well as the relative intensities for each pair of stars. This is part of an ongoing program to determine the masses of the individual stars and the distances to the binary systems.

Several improvements were made to the Observatory facilities. Mr. Baron constructed a high-speed photometer, for use with either telescope, that will allow recording of the intensity of variable sources and occultation data at red and blue wavelengths simultaneously. Mr. Baron, Dr. Edward Dunham, and several students have substantially increased the photographic capability of the Observatory by 1) instituting a procedure for baking plates in forming gas prior to exposure, 2) greatly reducing the periodic error in the drive of the 16-inch telescope, and 3) designing a more effective baffle system for the 16-inch telescope. A 35mm camera system was constructed for the 16-inch telescope, which will be used primarily for astrophotography by astronomy classes.

During IAP, over 70 members of the MIT community visited the Observatory on two open nights. Also, several students and the Observatory staff combined their efforts for a successful recovery of the new asteroid 1978 PB.

The student projects for Professor Elliot's course in observational astronomy (12.116) included photographing Saturn when its rings appeared edge on; measuring the nightly positions of selected asteroids; and photoelectric photometry of the short-period Cepheid variable star, CY Aqr. Students from Professor Pinson's astronomy classes (12.111, 12.112, 12.113, 12.114)

George R. Wallace, Jr. Astrophysical Observatory

visited the Observatory on several occasions during the fall and spring terms.

Two UROP projects are currently in progress, under the supervision of Dr. Dunham and Professor Elliot. One involves the search for new asteroids and the other the design and construction of a chopping photometer that would eliminate photometric noise caused by variable transparency of the Earth's atmosphere.

JAMES L. ELLIOT

Vice President and Dean of the Graduate School

Reports on Student Housing Development, for the Registrar, and for the Medical Department -- including those for the Environmental Medical Service, the Division of Laboratory Animal Medicine, and the Radioactivity Center -- follow the reports on the Graduate School which my associates in the Graduate Office and I have prepared.

DEAN OF THE GRADUATE SCHOOL

Tables of statistical information for the Graduate School appear at the end of this report. To facilitate ready comparison of this information for this year with past years, the data for 1979-80 are in the same format as in our past reports.

Inspection of these data indicates that there are no significant changes in recent trends -- most of which have been discussed in more detail in past reports. Our total graduate enrollment continues to grow and the engineering enrollment continues to be dominant. The number of master's degrees awarded increased at about the same rate as the number of doctor's degrees awarded. In recent years, the number of doctorates awarded has been declining relative to the master's degrees -- which is a worrisome national trend.

The patterns of student financial support have remained relatively stable although there is increased reliance upon support under the Federal College Work Study Program (CWSP) and upon individual student borrowing. Federal, foundation, and industrial fellowships -- regarded by many faculty and students as the "ideal" form of financial support for graduate effort -- continue to provide support for a relatively small fraction of the graduate body. While we and thus our students have benefited from the establishment of some new fellowship programs from industrial sources, the outlook for significant improvement in various Federal programs remains bleak. We continue our efforts to influence Federal sponsors to recognize that the "cost-of-education" allowances which we must accept in lieu of tuition and fees are falling far behind the latter and that the Fellows' stipends are also falling well behind any reasonable estimate of the Fellows' costs of living.

We are increasingly relying upon "Title IV" and "Title IX" programs administered in the new Federal Department of Education -- particularly those which are to be made available on the basis of student financial need (as distinct from merit). Thus, we are working with other universities and national groups to seek congressional authorization of adequate funding under these titles and to achieve a more "realistic" set of criteria to evaluate the financial need of graduate students. Current need criteria appear to be largely drawn from those which have gained almost universal acceptance over the last several decades for evaluating undergraduate financial need. Under these criteria, the students' parents are called upon to provide support and/or private financial information which our society seems to find tolerable at the undergraduate level but intolerable at the graduate level.

In my report for last year, I discussed the "political problems" we faced as a result of the Iranian revolution. At that time, we undertook a number of emergency measures, particularly to assist our Iranian students who found themselves cut off from sources of financial support for both tuition and living expenses. By the close of the last academic year, the situation seemed to have modified somewhat -- at least from the standpoint of the reopening of access to sources of financial support from Iran. A new form of crisis developed this year as a result of the taking of hostages in the US Embassy in Tehran. In mid-winter, the Immigration and Naturalization Service (INS) was ordered to "re-certify" the visas of all Iranian students. Considerable confusion

resulted from this order and several courts challenged its legality. Nevertheless, at the opening of spring term, most of our Iranian students had undergone the INS process and were "re-certified." Toward the end of spring term, the White House ordered the INS not to extend the duration of validity of visas which carried expiration dates (in the past, an extension had been almost automatically granted to a student in good standing who had not completed his/her academic program by the expiration date). There was also an implication that, in the near future, students whose visas were valid for "duration of study" might also find these invoked. Protests from a number of universities and by national educational groups -- led by the National Association of Foreign Student Advisors -- did succeed in the White House's rescinding of this deportation directive to the INS.

At the opening of the academic year, we anticipated that we might be faced with a large number of applicants for admission from the People's Republic of China (PRC). As we sought ways in which the Institute might most effectively respond to all of the new US-PRC initiatives, we were greatly aided by the knowledge and wisdom of many members of the faculty who are of Chinese origin. Institute Professor C. C. Lin was of particular help. We agreed to assess the credentials of such applicants in a quite "normal" fashion, and, in particular, not to mount any formal student exchange on a "bloc basis" with universities in the PRC. As the year progressed, it became clear that the Chinese emphasis for the near term would be on individual visitors such as visiting scholars or postdocs and on short-term visits of delegations.

The Committee on Graduate School Policy (CGSP) continued to provide the forum to ensure all-Institute faculty overview of the graduate programs and concerns of the individual departments, and to provide the guidance to those of us in the administration charged with implementing policies and procedures concerning graduate education. Through its several subcommittees, the CGSP dealt with a range of issues, of which the following are examples:

One subcommittee, chaired by Professor David Epstein, developed new criteria for the simultaneous awarding of two master's degrees. These criteria are more responsive to the current breadth of educational and research concerns in each department than were those they replace.

Another subcommittee, chaired by Professor Sylvain Bromberger, made significant improvements in the processes by which faculties of individual departments propose, review, and forward for CGSP approval new subjects of instruction. This subcommittee also revised and clarified the conditions under which pass/fail grades may be used and proposed a new definition of "J" (grade deferred). This latter change will be reviewed by the Committee on Academic Performance (CAP) for application at the undergraduate level and, if the CAP endorses the change, faculty action will be requested next fall. Finally, the CGSP subcommittee struggled valiantly to seek better criteria for determination of the "level" of credit for graduate subject -- of "graduate" or "graduate (A)" credit. The issue was not resolved by the close of the academic year so a new "task force" will be convened to seek resolution of this matter next year.

A subcommittee, chaired by Professor Mary Potter, undertook a department-by-department review of "academic due process" within each department. The subcommittee is concerned that each department has in place methods of communication which clearly indicate to graduate students what the faculty's requirements and expectations are and what the processes are which the student may engage if he/she feels aggrieved. Toward the end of the year the subcommittee reported on progress, emphasizing that there appeared to be no cause for great concern. The subcommittee plans to complete this work, present its findings and, if appropriate, specific recommendations for improvement next year.

The CGSP endorsed a special report on sexual harrasment which had been prepared by a task force sponsored by the Committee on Educational Policy and chaired by Professor Peter Elias.

Finally, an ad hoc task force composed of several members of the CGSP and several administrative staff undertook a comprehensive review of the conditions and limitations of appointments to the graduate staff. At this writing, the review and recommendations of the subcommittee are substantially completed. Consideration by the full CGSP and other appropriate councils will be scheduled next fall.

Last December the Provost of MIT and the Provost of the Woods Hole Oceanographic Institution appointed a special MIT faculty-WHOI research staff committee to review the 10-year old MIT-WHOI Joint Program in Oceanography to determine whether or not the program warranted continuation

and, if so, what recommendations might be made to improve the program. At this writing, the special committee has concluded that the program should be continued but that several changes should be effected for improvement. The report is in preparation, so that it should be ready for consideration at both institutions later in the summer and early fall.

Yvonne L. Whitaker, who began her career at the Graduate Office as a secretary in 1973 and who has served so capably as Assistant to the Dean since 1976, resigned at the close of this academic year to accompany her husband in a challenging new opportunity in northern Vermont. Leslie McIntyre of the secretarial staff has been promoted to succeed Ms. Whitaker. Ms. Whitaker's contribution to this report and those of Associate Deans Jeanne Richard and John B. Turner follow.

KENNETH R. WADLEIGH

GRADUATE WOMEN

In private universities, total graduate enrollment in fall 1979 was up 1.9 percent from the previous years. Other data compiled nationally indicate that the number of women enrolled continued to grow, increasing by 1 percent, while male enrollment decreased by 2 percent. In comparison with these numbers, MIT's total graduate enrollment increased by 5 percent in fall 1979. This change represented a 13 percent increase in the number of women and a 4 percent increase in the number of men enrolled. Of some concern is the decline in number of entering women graduate students, down 11 percent from 218 in 1978 to 193 in 1979. The overall increase of women graduate students is therefore explained by the increase in the number of continuing women students, up 26.5 percent from 388 to 480. The largest proportional increase in women enrolled was in the School of Humanities and Social Science, which rose from 22 percent to 28 percent. A 1 percent increase from 38 percent to 39 percent was experienced by the School of Architecture and Planning. One factor contributing to these increases may be the new non-resident doctoral thesis status, since more women are enrolled in these MIT programs, and the new policy has increased enrollments in these departments.

Admission statistics indicate an 8 percent decrease in the number of applications from women with a slight increase of 2 percent in male applicants. Contrary to the increase in women registered, the number of women applicants has decreased in both the School of Humanities and Social Science (-18 percent) and the School of Architecture and Planning (-6 percent). These changes could well be a reflection of job availability for individuals trained in these fields, although the male applicants do not reflect comparable decreases.

It is the Schools of Engineering and Science which reflect the largest proportion of graduate students at MIT and the number of women enrolled in these programs has not changed significantly. A 4 percent increase (representing 8 people) in women applicants in the School of Engineering does not keep pace with a 9 percent increase of male applicants. The static situation is further reflected in the proportion of women enrolled in Engineering departments which remains at 8 percent for both 1978 and 1979. Both male and female applicants in the Science departments decreased, -3 percent for women and -16 percent for men, while the number of women registered went from 188 to 207 or from 18 percent to 19 percent of the total enrollment.

Admissions and enrollment statistics indicate that in all Schools except Science, the percentage of women applicants accepted for admission is slightly higher than for male applicants. On the other hand, the percentage of applicants admitted who actually enroll, in general, shows a lower percentage for women than men, with the School of Science again the exception.

Of particular concern in this regard are the statistics for the School of Engineering, where 58 percent of the women were accepted for admission in 1979 and only 41 percent enrolled. Comparable figures for 1978 are not much better with 59 percent accepted and 53 percent enrolled.

There may be several reasons for this poor progress, but one contributing factor certainly is the limited pool of women applicants. This number is growing but the competition between universities for this small pool is keen. In addition, many women are being lured away from graduate

study in engineering fields by very attractive salary offers from industry. We may find we have to put forth greater efforts in order to attract more women to these graduate programs. Financial support is an absolute necessity but, in addition, women entering such non-traditional fields often need more encouragement and guidance since their backgrounds are often quite different from men who choose to enter these professions.

The proportion of women earning graduate degrees in science and engineering has risen sharply in the past 10 years at the national level; we have seen a similar trend at MIT. Recovering from a slight setback in the past two years, statistics for 1978-79 are more encouraging and indicate the number of women receiving advanced degrees has reached the highest percentage record in recent years. The total of 206 women who earned advanced degrees is more than double the total of 95 women who received such degrees in 1973-74.

The 47 women doctoral degree recipients in 1978-79 were only three fewer than our all-time high of 50 in 1976-77. The number of master's degrees awarded to women has increased steadily over the years, and the 156 recipients this year represent a 7.5 percent increase over 1978-79.

As Dean Wadleigh observes in his report, the financial support picture for the graduate students has not brightened during the past year. Tuition and living costs continue to escalate while fewer fellowship programs are available.

The situation for women graduate students continues to be disproportionately affected since the largest proportion of women still tend to enroll in those programs at MIT whose financial resources are most limited. Some relief for students in the social science departments has been realized with the new non-resident thesis writing status, as is reflected in increased enrollment of continuing women students in these areas.

Our seventh annual competition for the Ida M. Green Fellowships resulted in the selection of eight women for these awards (including one honorary award). In addition, one continuing woman graduate student was awarded a Collamore-Rogers Fellowship. These fellowships represent the only endowed funds earmarked for the support of women at MIT. A cross section of MIT's departments is represented by these women scholars, and such funds are important in attracting and increasing the number of qualified women in MIT's graduate programs.

In recent years graduate women at MIT have been recipients of awards from the International Business Machines Corporation and the Xerox Special Opportunity Fellowship Programs for Minorities and Women pursuing graduate study in specific areas of interest to these companies. Two women held IBM awards during 1979-80 and three women (2 minority) received support from the Xerox program. Graduate women also received fellowships in national competitions from the American Association of University Women, the National Science Foundation, the Hertz Foundation, the National Institute of Mental Health, and Bell Laboratories for their graduate studies at MIT.

Several fellowship programs are being discontinued or phased out. The Danforth Foundation after nearly 30 years of providing support for graduate students has ended its program with the selection of a final "class" of Fellows this year. This program provided support for doctoral degree candidates interested in becoming university teachers. In recent years, especially, this has been an important financial resource for women as indicated by the fact that three of the four Danforth Fellows at MIT this year were women.

The National Fellowship Fund and the Graduate Fellowship Fund for Mexican Americans, Puerto Ricans, and American Indians are also being phased out. These programs provided support for many minority graduate students at MIT during recent years. This past year, of the four National Fellowship holders continuing their graduate studies at MIT, one was a woman, and one of the two recipients of the Graduate Fellowships was a woman.

At the present time, few financial resources are available for women specifically; therefore, it is anticipated that increasing numbers of women will have to compete for funding from existing Federal, foundation, and industrial fellowship programs.

JEANNE E. RICHARD

MINORITY GRADUATE STUDENTS

There seems to be an unnerving parallel between the country's "sagging economy" and efforts to increase the number of minority persons enrolled in graduate school. As our economy plummets deeper and deeper, the enrollment of minority graduate students follows a similar course. The national trend over the past three years has been for fewer and fewer minority students to go on to graduate school.

We have witnessed a similar decline in minority graduate student enrollment at MIT over the past three years, moving from a high of 178 students in 1976 to our current low of 144 for the fall term of 1979. The decline in minority graduate student enrollment is especially distressing when we observe that the total graduate student enrollment at MIT has been steadily increasing the past 10 years at about 5 percent more students each year. Why then the decline in minority graduate student enrollment?

A depressed economy has already been cited as a possible cause for fewer minority students opting for post-baccalaureate study. The sad state of affairs in the economy has caused a number of foundations, philanthropic organizations, and governmental agencies who had previously offered fellowships to minority students to either reduce their support or go out of business altogether. The end result is fewer fellowships for minority students to pursue advanced study. When faced with the choice of going on to graduate school with little or no financial support, or taking a job that pays \$20,000 to \$25,000, the minority student has in many cases chosen the job. The student feels that with the job he/she will be in a much better position to help their family as well as buy all those things projected in the "American Dream." It becomes extremely difficult for the student to delay immediate need gratification and pursue a rigorous course of graduate study that may or may not have as many financial rewards five years from now as the job offer from industry or government provides. A tight economy forces the minority student, especially, to make his/her decision about career, training, and education on the basis of available financial resources right now rather than what is best for the person and his/her future in the long run. Graduate institutions will have to further intensify their efforts to work with undergraduate institutions, private industry, government, and society in general to inform and counsel minority students about graduate school opportunities, and the need to have persons from all sectors of our society enrolled in its student body -- if we are going to have a nation that is broadly represented in all walks of life.

A continuing problem and reason for the declining numbers in minority graduate student enrollment is the small pool of minority applicants to choose from for graduate study, especially in the sciences and engineering. We just don't have that many minority students graduating from college in physics, mathematics, chemistry, and biology. The few who do graduate and have good grades will in most cases go to medical, dental, law, or business school (again primarily for financial reasons). There are very few students to recruit or convince to come to graduate school in the physical sciences.

Engineering provides a few more minority graduates than the science fields, but most of the engineering minority graduates are heavily recruited by industry and large engineering enterprises upon receiving the bachelor's degree. Graduate engineering schools find it extremely difficult to convince a minority youngster to go to graduate school versus going immediately to work. We are hopeful that through MIT's continued participation in the National Consortium for Graduate Degrees for Minorities in Engineering, Inc. and Lincoln Laboratory's Summer Program for Engineers and Scientists, as well as our recruitment efforts at the six black engineering schools and from MIT's undergraduate minority body, we will be able to increase our numbers in the engineering fields.

Minority graduate students at MIT comprise about 3.5 percent of the total graduate enrollment, with the largest concentration of minority students in Urban Studies and Planning (19.9 percent) and Architecture (7.1 percent). Five departments reported no minority students enrolled in their departments for 1979-80: Ocean Engineering, Linguistics and Philosophy, Psychology, Interdisciplinary Science, and Meteorology. I should also note that the Health Sciences and Technology Program (HST) had no minority students as well.

Applications from minority students are still very low, with only 195 students applying for 1979-80, and almost half of that number (92) were admitted to MIT for graduate study. Only 45 of the 92

actually enrolled in MIT for the fall term. Most of the "summer melt" took place in a few departments: the Sloan School lost 14 of the 18 students to which admission was offered; Physics lost five of the 10 offered admission; and Political Science lost five of the six students offered admission. Several departments enrolled no new minority students for 1979-80; they were: Chemical Engineering, Ocean Engineering, Economics, Linguistics and Philosophy, Psychology, Earth and Planetary Sciences, Interdisciplinary Science, Mathematics, Meteorology, and HST. Not very far behind the above departments were seven other departments, each of which enrolled only one new minority student for 1979-80. Altogether there were 15 departments out of the 23 graduate departments which enrolled one or less new minority students in the fall of 1979. It is clear that a few departments at MIT are "carrying the load," so to speak, in aggressively seeking and attracting minority graduate students to the Institute. We must do better and I am sure we will with the help of faculty, students, and staff!

JOHN B. TURNER

GRADUATE STUDY ABROAD

This year the Committee on Foreign Scholarships, under the continued chairmanship of Eugene R. Chamberlain, Associate Dean for Student Affairs and International Student Advisor, reviewed 18 applications for three competitions for grants for graduate study abroad. Eleven applications were submitted for the Fulbright-Hays program administered by the Institute of International Education (IIE), four applications were submitted for the German Academic Exchange Service (DAAD) Direktstipendien, and three students applied for the Winston Churchill Foundation Scholarship program.

In the IIE competition, Pamela J. Langer, a graduate student in Biology, won an International Telephone and Telegraph (ITT) Fellowship for a year in Kenya. Of the remaining 10 applicants in this competition, three passed the National Screening Committee's preliminary application stage, and two were awarded Fulbright-Hays grants for 1980-81. They are: Frances Hagopian, a graduate student in Political Science, for research in Brazil, and Joseph V. Micallef, also a graduate student in Political Science, for research in Italy. The third student who passed the National Screening Committee, David E. Runkle, won a DAAD Direktstipendien.

The Committee nominated two principal and two alternate candidates for the DAAD Direktstipendien for graduate study in the Federal Republic of Germany. Three of our nominees won awards. They are: Daniel L. Metzger, a senior in Chemistry; David E. Runkle, a graduate student in Economics; and Thomas A. Russ, a senior in Electrical Engineering and Computer Science.

The Foreign Scholarship Committee nominated three candidates for the Winston Churchill Foundation Scholarship program for a year of graduate study at Churchill College, Cambridge University. Although two of these students were finalists in the competition, neither received an award.

It should also be noted that Bruce Allen, a senior in Physics, won a Marshall Scholarship for graduate study at Cambridge University; Barry J. Nalebuff, a senior in Mathematics, won a Rhodes Scholarship to Oxford University; and Janet S. Wager, a graduate student in Linguistics, won an HEW Doctoral Dissertation Research Abroad Grant to Morocco.

In spite of the increased attempts to publicize the availability of these scholarships, the Foreign Scholarship Committee still receives about the same number of applications each year. The applicants, however, are usually excellent students with good credentials and sound projects, so MIT has a good record in these competitions. The Committee continues to believe that it is important for students in their early undergraduate years to be aware of these scholarship opportunities in order that they may plan their curriculum, especially their foreign language courses, accordingly so that they will have adequate preparation for studying abroad.

YVONNE L. WHITAKER

STUDENT HOUSING DEVELOPMENT

I have had an active role in the Institute's development of new student housing and large-scale housing renovations for almost two decades. In almost every September of these 19 years, I believe I recall a "housing crisis" of one form or another. Unfortunately, our projections for this coming September indicate that there will not be any cessation in this continuity of crises. Students who must look to off-campus resources will be most affected, particularly single graduate students and married undergraduates and graduates.

I am frankly proud of the progress we have made in building new student housing and renovating older buildings during the sixties and seventies. Nevertheless, I must regret that we simply have not been able to find adequate financial resources to keep pace with the demand for on-campus housing. Further, our on-campus problems have been compounded by the decreasing availability, year after year, of rental housing stock in the greater Boston area.

I reported last year that we had been forced by city opposition to abandon our exploration of the acquisition and renovation of an old hotel in Boston. This year we ran into similar opposition which forced us to abandon plans to acquire and renovate a large brownstone in Back Bay for fraternity occupancy. Currently, although we continue to test the possibilities of acquisition of existing housing resources off-campus -- probably for single graduate and married student occupancy -- we have no active plans for a specific off-campus project.

New construction is enormously expensive. The associated debt service even under "favorable" Massachusetts Health and Educational Facilities Authority (MHEFA) financing is prohibitively high for student rental structures. Thus, large fractions of the costs of new construction must be in the form of "gift capital." Furthermore, with the construction of "Next House," (upon which I reported last year) now under way, we will have used the last available site for housing on the current campus holdings. We also have agreed to delay any further plans for developing the so-called "Northwest" or "Simplex" area, north and west of the athletic fields until a joint planning effort with the City of Cambridge is completed -- a year or two hence.

Two planning efforts to explore ways to cope with these problems have been authorized. One study is sponsored by the Alumni Interfraternity Conference in close cooperation with the Institute. This study is intended to update information on physical and safety conditions of our 30-odd independent residences, and to identify costs and financing mechanisms to effect correction of conditions judged to be unsatisfactory and/or below standards.

The second planning effort will be undertaken as an institutional planning function, to perform a comprehensive updating of renovation requirements of our current institutional housing stock, to assess current and potential future goals for new acquisition and/or construction, and to lay out a program toward accomplishing these goals.

With the opening of "Next House" in the fall of 1981, we will be able to fully implement our undergraduate housing policy, including reductions in current overcrowding and the provision of housing to college transfer students and upperclass students returning to campus after some absence. For the undergraduate program, there remain problems associated with meeting the residential preferences of our increasing population of undergraduate women, of upgrading Senior House and East Campus, and of the future use and possible upgrading of Bexley Hall and Random Hall.

As I indicated earlier, I believe the more difficult challenge in this planning task will be to identify mechanisms which will provide for major increments in housing available to all married students and single graduate students.

As a modest step in identifying some additional capacity for this latter group and at the same time as a first step toward developing Walker Memorial into a more viable center for graduate life, I suggested in mid-year a "swapping" of facilities. This involved increasing the capacity of Next House to 350 (from the original planning goal of 300) and devoting Next House and Ashdown House to undergraduate occupancy, while converting Senior House and East Campus, after appropriate renovations, for single graduate student occupancy. Suffice it to say that this suggestion created one of the major controversies of the year -- with occupants of each House involved voicing objections to such notions with varying but considerable degrees of intensity. Given all of the other

Vice President and Dean of the Graduate School

problems created by the transition to a new commons meals program, my associates in the Office of the Dean for Student Affairs and I decided not to move this consideration to a formal proposal for study -- at least not during the foreseeable future. Put another way, I announced "active burial of the pre-proposal."

I cannot assess what negative feelings may exist in the aftermath of this set of discussions but I do find two positive aspects in the outcome. First, we did learn firsthand that all of our past efforts to enhance the development of house spirit, pride, and identity have clearly been successful. Second, we did find the addition of 50 beds to Next House to be a wise change to the original program both for economic as well as design reasons. Accordingly, we will have 50 additional beds available for student occupancy in Next House than would otherwise have been the case.

I hope next year to be able to report in a more definitive and positive fashion as a result of the planning studies now under way.

KENNETH R. WADLEIGH

For simple comparison with data for 1978-79, the following statistical information for 1979-80 is presented in the same format as the corresponding data in the report for 1978-79.

TABLE I
REGULAR GRADUATE STUDENT ENROLLMENT, FALL TERM 1979

	Foreign ⁽¹⁾	Women ⁽²⁾	Minority ⁽³⁾	Total	Non-Residents ⁽⁴⁾
School of Architecture and Planning	88(- 3)	133(+ 6)	47(+1)	343(+ 8)	1
School of Engineering	685(+50)	168(+22)	44(0)	1978(+125)	2
School of Humanities and Social Science	101(+16)	100(+34)	17(+1)	358(+ 59)	45
Sloan School of Management	101(- 1)	76(- 3)	9(-4)	391(+ 3)	1
School of Science	241(+12)	206(+19)	33(+5)	1067(+ 4)	6
Health Sciences and Technology	3(0)	1(0)	0	9(+ 3)	0
TOTAL	1219(+74)	684(+78)	150(+3)	4146(+202)	55

(1) Includes Canadians

(2) See also Table IX

(3) Includes Black Americans, Puerto Ricans, Mexican-Americans, and American Indians

(4) Included in totals

Numbers in parentheses indicate the changes from 1978-79 to 1979-80.

TABLE II
GRADUATE DEGREES AWARDED, 1979-80

Advanced Degrees Conferred	M.C.P., M. Arch., M. Arch. A.S.	S.M.	Engineer	Sc.D.	Ph.D.	Total
September 1979 Woods Hole	20(+3)	174(-11)	15(+4) 1(0)	11(-2)	99(+16) 0(- 4)	320(+ 6)
February 1980 Woods Hole	14(-4)	241(+34)	17(-3) 1(+1)	23(+4)	99(- 4) 10(+ 7)	405(+35)
June 1980 Woods Hole	56(-7)	482(- 2)	44(+14) 0(- 3)	18(-1) 1(0)	123(-11) 4(+ 2)	728(- 8)
TOTAL	90(-8)	897(+21)	78(+13)	53(+1)	335(+ 6)	1453(+33)

Numbers in parentheses indicate change from 1978-79.

TABLE III

A "SNAPSHOT" OF GRADUATE STUDENT SUPPORT "FULL AWARDS"

The following sources provided at least full tuition support for graduate students during the fall term 1979. Total regular graduate student enrollment, not including non-residents, was 4,091.

	<u>Numbers of Students</u>	<u>Percent Total Enrollment</u>	<u>Change from 78-79</u>
FELLOWSHIPS AND TRAINEESHIPS AWARDED BY MIT			
NIH and NIMH Traineeships	121		- 5
NSF National Needs Traineeships	4		- 5
DOE Traineeships	0		- 6
HUD Minority Intern Program	5		- 5
HEW Domestic Mining and Mineral Fuel Traineeships	9		- 4
HEW Graduate and Professional Opportunities Program Fellowships	18		+ 9
HEW Public Service Education Traineeships	10		+ 6
MIT Endowed and Other Fund Fellowships	206		- 2
Industrial and Foundation Fellowships	159		+ 29
	<u>532</u>	<u>13%</u>	<u>+ 17</u>
FELLOWSHIPS AWARDED BY SPONSORS TO MIT STUDENTS			
NSF Graduate Fellowships	120		- 10
NIMH Fellowships	4		- 4
Hertz Foundation Fellowships	41		+ 10
EPA Fellowships	0		- 1
Department of Labor Fellowships	0		- 1
	<u>165</u>	<u>4%</u>	<u>- 6</u>
STUDENT ASSISTANTSHIPS			
Research Assistants	1498		+ 54
Teaching Assistants	535		+ 54
Instructor-G	22		+ 6
	<u>2055</u>	<u>50%</u>	<u>+114</u>
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, Air Force, Coast Guard	38		+ 2
US Navy and Related Programs	24		- 4
Foreign Countries and International Programs	302		- 8
Industry and Foundation (US)	108		- 9
	<u>472</u>	<u>12%</u>	<u>- 19</u>
SUMMARY BY SOURCES - FULL AWARDS			
Federal Fellowships and Traineeships	291	7%	- 26
Graduate Student Staff	2055	50%	+114
Industrial and Foundation Awards	200	5%	+ 39
MIT Endowed and Budgeted Funds	206	5%	- 2
Students Sponsored by External Sources	472	12%	- 19
	<u>3224</u>	<u>79%</u>	<u>+106</u>

TABLE IV
TRENDS IN GRADUATE STUDENT SUPPORT
(\$000's)

The numbers in parentheses are the "normalized" data. To "normalize" the dollar amounts these have been divided by the product (total regular graduate students registered fall term) (tuition for the 9-month academic year).

	Fellowships Traineeships Scholarships*	Staff Tuition Awards (TA)	Staff Salaries (RA & TA)	MIT Only	Loans Including Outside Agencies
1968-69	4,994 (.710)	1,033 (.147)	6,015 (.855)	646 (.092)	na
1969-70	5,197 (.712)	1,056 (.145)	6,815 (.934)	470 (.064)	643 (.088)
1970-71	5,396 (.655)	1,182 (.143)	6,850 (.831)	483 (.059)	672 (.082)
1971-72	5,076 (.589)	1,294 (.150)	7,086 (.823)	696 (.080)	827 (.096)
1972-73	4,687 (.486)	1,432 (.150)	7,991 (.828)	754 (.078)	916 (.095)
1973-74	3,930 (.378)	1,453 (.140)	8,781 (.844)	852 (.082)	1,014 (.097)
1974-75	3,693 (.318)	1,738 (.150)	9,760 (.840)	1,075 (.093)	1,293 (.111)
1975-76	3,447 (.259)	1,878 (.141)	10,878 (.816)	1,141 (.086)	1,407 (.106)
1976-77	3,545 (.229)	2,065 (.137)	11,654 (.772)	1,419 (.094)	2,013 (.133)
1977-78	3,418 (.205)	1,978 (.118)	12,479 (.750)	1,391 (.084)	2,201 (.132)
1978-79	3,667 (.198)	2,355 (.127)	15,251 (.823)	962 (.052)	2,387 (.129)
1979-80	3,733 (.172)	3,079 (.142)	16,610 (.766)	976 (.045)	2,466 (.113)

* Administered by the Graduate School Office

TABLE V
DISTRIBUTION OF FUNDING FOR GRADUATE STUDENT TUITION AND LIVING EXPENSES
FALL TERM 1979*

<u>Estimates of Required Funding</u>		
Tuition	\$10,405,835	
Stipend (\$510/mo. for 4½ months)	8,971,640	
Total Estimated Required Funding	\$19,377,475	
<u>Identified Support by Category</u>		
Research Assistantships	\$ 6,298,751	(32.5%)
Teaching Assistantships	2,301,416	(11.8%)
Federal Fellowships and Traineeships	1,265,032	(6.5%)
General and Endowed Support (Departmentally controlled)	600,876	(3.0%)
General and Endowed Support (Graduate School Office controlled)	334,531	(1.7%)
Outside Industrial/Foundation	311,542	(1.5%)
Outside Sources Administered by Departments	600,735	(3.0%)
Outside Sources Administered by Graduate School Office	95,200	(.5%)
Outside Sources, Direct Billing to Sponsor by Institute, Tuition Only	828,152	(4.0%)
Total Identified Support	\$12,636,235	(64.5%)
Loans	1,320,859	(7.0%)
College Work-Study Program Eligibility	437,576	(2.0%)

* Note that the corresponding data for last year were presented on an academic year (9-month) basis.

TABLE VI
DOCTORAL DEGREES AWARDED EACH YEAR BY SCHOOL AND CITIZENSHIP

Each number is the total of the degrees awarded in September, February, and June of the academic year indicated. The numbers in parentheses are the number of degrees awarded divided by the corresponding enrollment.

Academic Year		Arch.	Eng'g.	Hum. & Soc. Sci.	Sloan	Science	Total
1969-70	Citizen	3 (.024)	111 (.103)	42 (.206)	9 (.041)	135 (.171)	300 (.125)
	Foreign	2 (.035)	78 (.162)	14 (.180)	5 (.045)	40 (.156)	139 (.141)
	Total	<u>5</u>	<u>189</u>	<u>56</u>	<u>14</u>	<u>175</u>	<u>439</u>
1970-71	Citizen	2 (.011)	116 (.108)	30 (.152)	10 (.043)	144 (.190)	302 (.124)
	Foreign	1 (.026)	59 (.123)	7 (.125)	2 (.022)	29 (.134)	98 (.114)
	Total	<u>3</u>	<u>175</u>	<u>37</u>	<u>12</u>	<u>173</u>	<u>400</u>
1971-72	Citizen	5 (.028)	102 (.095)	36 (.191)	4 (.019)	149 (.212)	296 (.126)
	Foreign	1 (.020)	60 (.123)	9 (.143)	3 (.030)	49 (.249)	122 (.136)
	Total	<u>6</u>	<u>162</u>	<u>45</u>	<u>7</u>	<u>198</u>	<u>418</u>
1972-73	Citizen	4 (.022)	112 (.107)	34 (.160)	4 (.017)	122 (.169)	276 (.115)
	Foreign	1 (.020)	54 (.114)	17 (.274)	3 (.024)	45 (.208)	120 (.129)
	Total	<u>5</u>	<u>166</u>	<u>51</u>	<u>7</u>	<u>167</u>	<u>396</u>
1973-74	Citizen	6 (.034)	93 (.088)	29 (.136)	5 (.021)	129 (.179)	262 (.109)
	Foreign	1 (.016)	49 (.099)	18 (.273)	6 (.052)	42 (.196)	116 (.122)
	Total	<u>7</u>	<u>142</u>	<u>47</u>	<u>11</u>	<u>171</u>	<u>378</u>
1974-75	Citizen	7 (.037)	104 (.095)	31 (.143)	10 (.040)	110 (.146)	262 (.105)
	Foreign	2 (.033)	56 (.107)	10 (.154)	8 (.080)	24 (.110)	100 (.103)
	Total	<u>9</u>	<u>160</u>	<u>41</u>	<u>18</u>	<u>134</u>	<u>362</u>
1975-76	Citizen	1 (.005)	83 (.073)	49 (.232)	12 (.055)	126 (.162)	271 (.106)
	Foreign	1 (.019)	67 (.114)	7 (.119)	2 (.017)	42 (.180)	119 (.113)
	Total	<u>2</u>	<u>150</u>	<u>56</u>	<u>14</u>	<u>168</u>	<u>390</u>
1976-77	Citizen	6 (.026)	79 (.068)	33 (.155)	2 (.007)	125 (.156)	245 (.090)
	Foreign	4 (.071)	64 (.106)	19 (.264)	1 (.010)	46 (.199)	134 (.126)
	Total	<u>10</u>	<u>143</u>	<u>52</u>	<u>3</u>	<u>171</u>	<u>379</u>
1977-78	Citizen	5 (.023)	111 (.096)	50 (.240)	8 (.029)	119 (.146)	293 (.110)
	Foreign	3 (.039)	66 (.103)	13 (.169)	15 (.139)	35 (.141)	132 (.115)
	Total	<u>8</u>	<u>177</u>	<u>63</u>	<u>23</u>	<u>154</u>	<u>425</u>
1978-79	Citizen	10 (.041)	80 (.066)	35 (.164)	10 (.035)	126 (.151)	261 (.093)
	Foreign	3 (.033)	64 (.101)	11 (.130)	9 (.088)	33 (.142)	120 (.105)
	Total	<u>13</u>	<u>144</u>	<u>46</u>	<u>19</u>	<u>159</u>	<u>381</u>
1979-80	Citizen	8 (.031)	96 (.074)	40 (.156)	5 (.017)	127 (.153)	276 (.094)
	Foreign	3 (.034)	66 (.096)	11 (.109)	3 (.029)	28 (.115)	111 (.091)
	Total	<u>11</u>	<u>162</u>	<u>51</u>	<u>8</u>	<u>155</u>	<u>387</u>

TABLE VII
 WOMEN GRADUATE STUDENT ENROLLMENT
 (% of Total 1973-1979)

<u>Fall Term</u>	<u>New</u>			<u>Continuing</u>			<u>Total</u>		
	<u>Women</u>	<u>Total</u>	<u>% of Women</u>	<u>Women</u>	<u>Total</u>	<u>% of Women</u>	<u>Women</u>	<u>Total</u>	<u>% of Women</u>
1973	105	1080	10%	213	2278	9 %	318	3358	9 %
1974	140	1061	13%	265	2407	11 %	405	3468	12 %
1975	175	1113	16%	312	2490	12.5%	487	3603	13.5%
1976	185	1220	15%	361	2554	14 %	546	3774	14 %
1977	192	1184	16%	367	2640	14 %	559	3824	14.6%
1978	218	1259	17%	388	2685	14 %	606	3944	15.4%
1979	193	1202	16%	491	2844	17 %	684	4046	16.5%

TABLE VIII
WOMEN GRADUATE STUDENT ENROLLMENT

Comparison of Fall Term Enrollments - 1978 and 1979

	<u>Number of Women</u>		<u>% of Women in Total Enrollment</u>	
	<u>1978</u>	<u>1979</u>	<u>1978</u>	<u>1979</u>
<u>School of Architecture and Planning</u>				
Architecture IV	60	61	32%	34%
Urban Studies & Planning XI	67	72	46%	45%
	<u>127</u>	<u>133</u>	<u>38%</u>	<u>39%</u>
<u>School of Engineering</u>				
Aeronautics & Astronautics XVI	7	6	5%	4%
Chemical Engineering X	27	35	14%	16%
Civil Engineering I	15	21	6%	8%
Electrical Engineering & Computer Science VI, VI-A, VI-W	45	46	9%	9%
Materials Science III, III-B, III-W	24	26	15%	15%
Mechanical Engineering II, II-T, II-W	16	23	5%	7%
Nuclear Engineering XXII	9	8	5%	2%
Ocean Engineering, XIII, XIII-A, XIII-B, XIII-W	3	3	2%	5%
	<u>146</u>	<u>168</u>	<u>8%</u>	<u>8%</u>
<u>School of Humanities and Social Science</u>				
Economics XIV	16	19	13%	15%
Linguistics/Philosophy XXIV	18	27	39%	40%
Political Science XVII	23	42	23%	33%
Psychology IX	9	12	36%	35%
	<u>66</u>	<u>100</u>	<u>22%</u>	<u>28%</u>
<u>Sloan School of Management</u>				
Management XV	68	63	22%	20%
XV-A (Fellows)	5	7	9%	13%
XV-B (Operations Research)	6	6	26%	26%
	<u>79</u>	<u>76</u>	<u>20%</u>	<u>19%</u>
<u>School of Science</u>				
Biology VII	34	33	32%	30%
VII-W	5	4	28%	21%
Chemistry V	34	30	19%	16%
Earth & Planetary Sciences XII	15	11	18%	14%
XII-W	13	14	30%	32%
Mathematics XVIII	13	18	12%	16%
Meteorology XIX	2	1	5%	2%
XIX-W	3	3	20%	25%
Nutrition & Food Science XX	51	62	29%	35%
Physics VIII	14	20	5%	7%
Interdisciplinary Science XXV	3	10	21%	67%
HST	1	1	16%	11%
	<u>188</u>	<u>207</u>	<u>18%</u>	<u>19%</u>
TOTALS	606	684	15.4%	16.5%

TABLE IX-A

COMPARISON OF ADMISSIONS STATISTICS FOR GRADUATE WOMEN AND GRADUATE MEN

Number of Applicants 1978/Number of Applicants 1979

Numbers in parentheses indicate the percent change in number of applicants from 1978 to 1979.

	<u>Women</u>	<u>Men</u>
School of Architecture and Planning	330/ 309(- 6%)	547/ 605(+10 %)
School of Engineering	180/ 188(+ 4%)	2273/2475(+ 9 %)
School of Humanities and Social Science	166/ 136(-18%)	453/ 447(- 1 %)
Sloan School of Management	293/ 303(+ 3%)	1214/1183(- 2.5%)
School of Science	366/ 353(- 3%)	1314/1237(- 6 %)
	1335/1289(- 8%)	5801/5947(+ 2 %)

TABLE IX-B

APPLICATIONS/ADMISSION/ENROLLMENT

Statistics for Men and Women
Fall 1978 and Fall 1979

	<u>Received</u>	<u>Admitted</u>		<u>Enrolled</u>	
	% women of total applicants	% women applicants admitted	% men applicants admitted	% women admitted who enrolled	% men admitted who enrolled
<u>Architecture and Planning</u>					
1978	39%	22%	18%	59%	69%
1979	34%	26%	21.5%	49%	51%
<u>Engineering</u>					
1978	7%	59%	46%	53%	52%
1979	7%	58%	38%	41%	58%
<u>Humanities and Social Sciences</u>					
1978	27%	31%	25%	48%	54%
1979	23%	29%	25%	56%	52%
<u>Sloan School of Management</u>					
1978	19%	30%	24%	44%	54%
1979	20%	22%	23%	57%	63%
<u>Science</u>					
1978	22%	31%	38%	48%	42%
1979	22%	33%	39%	42%	35%
<u>TOTALS</u>					
1978	19%	32%	35%	50%	51%
1979	18%	32%	32%	47%	52%

TABLE X
COMPARISON, IN NUMBERS, OF DEGREES AWARDED TO MEN AND WOMEN

	Master's			Doctor's			Engineer's			All		
	Women	Total	% of Women	Women	Total	% of Women	Women	Total	% of Women	Women	Total	
1973-74	58	832	7%	34	378	9%	3	102	3%	92*	1210*	7.6%*
										95	1312	7%
1974-75	80	856	9%	32	362	9%	0	107	0%	112*	1218*	9%*
										112	1325	8.4%
1975-76	93	862	11%	32	320	10%	2	94	2%	125*	1182*	13%*
										127	1276	10%
1976-77	145	971	15%	50	379	13.4%	2	91	2%	196*	1350*	14.5%*
										198	1441	13.7%
1977-78	134	934	14%	48	425	11%	5	108	5%	182*	1359*	13.4%*
										187	1467	12.7%
1978-79	145	968	15%	29	387	7%	2	65	3%	174*	1355*	12.8%*
										176	1420	12.3%
1979-80	156	984	16%	47	386	12%	3	77	4%	203*	1370*	15%*
										206	1447	14%

* without Engineer's degrees

TABLE XI
DEGREES AWARDED TO WOMEN BY SCHOOL

	<u>1971-72</u>	<u>1972-73</u>	<u>1973-74</u>	<u>1974-75</u>	<u>1975-76</u>	<u>1976-77</u>	<u>1977-78</u>	<u>1978-79</u>	<u>1979-80</u>
<u>Architecture and Planning</u>									
Master's	12	23	13	23	23	34	23	33	41
Doctor's	1	1	1	2	0	2	4	3	5
<u>Engineering</u>									
Master's	12	14	22	16	21	28	42	50	51
Doctor's	2	0	3	3	3	8	4	4	7
<u>Humanities and Social Science</u>									
Master's	2	0	3	4	3	5	4	3	3
Doctor's	5	10	10	8	10	10	12	4	12
<u>Sloan</u>									
Master's	10	3	11	21	26	46	40	45	34
Doctor's	0	0	0	0	0	0	2	0	1
<u>Science</u>									
Master's	6	11	9	16	19	32	25	14	27
Doctor's	23	13	20	19	19	28	25*	18	22*
<u>Operations Research</u>									
	0	0	0	0	1(SM)	0	1(SM)	0	0
							1(Ph.D.)		
<u>WHOI</u>									
	0	0	0	0	1(Ph.D.)	2(Ph.D.)	2(Ph.D.)	0	(2 Ph.D. included in VII & XII)
							included in VII & XII		
<u>TOTALS</u>									
Master's	42	51	58	80	93	145	135	145	156
Doctor's	31	24	34	32	33	50	48	29	47

* includes 2 WHOI degrees

TABLE XII
GRADUATE DEGREES AWARDED TO MINORITY STUDENTS

September, February, June
1979-80

	<u>Blacks</u>	<u>Hispanics</u>	<u>Native Americans</u>	<u>Totals</u>
Master's	25	7	0	32
Engineer's	0	0	0	0
Doctor's	<u>5</u>	<u>5</u>	<u>0</u>	<u>10</u>
TOTALS	30	12	0	42

TABLE XIII
MINORITY GRADUATE STUDENT ENROLLMENT

Fall 1979

	<u>Black</u>	<u>Hispanic</u>	<u>Native American</u>	<u>Total Minority Graduate Students</u>	<u>Total Other Graduate Students</u>	<u>% of Total</u>
<u>Architecture and Planning</u>						
Architecture	11(1)	2(1)	0	13(2)	182	7.1%
Urban Studies & Planning	23(12)	9(4)	0	32(16)	161	19.8%
	<u>34(13)</u>	<u>11(5)</u>	<u>0</u>	<u>45(18)</u>	<u>343</u>	<u>13.1%</u>
<u>Engineering</u>						
Aeronautics & Astronautics	4(0)	2(1)	0	6(1)	151	3.9%
Chemical Engineering	4(0)	0	0	4(0)	215	1.8%
Civil Engineering	5(1)	2(0)	0	7(1)	252	2.7%
Electrical Engineering & Computer Science	11(4)	2(1)	1	14(5)	533	2.6%
Materials Science	1(0)	1(1)	0	2(1)	176	1.1%
Mechanical Engineering	6(1)	4(2)	0	10(3)	336	2.9%
Nuclear Engineering	2(0)	2(1)	0	4(1)	172	2.3%
Ocean Engineering	0	0	0	0	143	0.0%
	<u>33(6)</u>	<u>13(6)</u>	<u>1</u>	<u>47(12)</u>	<u>1978</u>	<u>2.3%</u>
<u>Humanities and Social Science</u>						
Economics	4(0)	0	0	4(0)	128	3.1%
Linguistics & Philosophy	0	0	0	0	67	0.0%
Political Science	4(0)	1(1)	0	5(1)	129	3.8%
Psychology	0	0	0	0	34	0.0%
	<u>8(0)</u>	<u>1(1)</u>	<u>0</u>	<u>9(1)</u>	<u>358</u>	<u>2.5%</u>
<u>Sloan School of Management</u>						
	9(4)	0	0	9(4)	391	2.3%
<u>Science</u>						
Biology	2(0)	3(1)	0	5(1)	130	3.8%
Chemistry	4(1)	4(2)	0	8(3)	187	4.2%
Earth & Planetary Sciences	0	1(0)	0	1(0)	122	0.8%
Interdisciplinary Science	0	0	0	0	15	0.0%
Mathematics	0	1(0)	0	1(0)	113	0.8%
Meteorology	0	0	0	0	53	0.0%
Nutrition & Food Science	3(1)	2(0)	0	5(1)	179	2.7%
Physics	11(3)	3(2)	0	14(5)	268	5.2%
HST	0	0	0	0	9	0.0%
	<u>20(5)</u>	<u>14(5)</u>	<u>0</u>	<u>34(10)</u>	<u>1076</u>	<u>3.1%</u>
TOTALS	104(28)	39(17)	1	144(45)	4146	3.4%

() = new students

TABLE XIV
MINORITY APPLICANTS ADMITTED AND ENROLLED

	1978-79 vs 1979-80			1978-79 vs 1979-80		
	<u>1978-79</u>			<u>1979-80</u>		
	<u>received</u>	<u>admitted</u>	<u>enrolled</u>	<u>received</u>	<u>admitted</u>	<u>enrolled</u>
<u>Architecture and Planning</u>						
Architecture	15	9	9	15	4	2
Urban Studies & Planning	60	15	14	56	23	16
	<u>75</u>	<u>24</u>	<u>23</u>	<u>71</u>	<u>27</u>	<u>18</u>
<u>Engineering</u>						
Aeronautics & Astronautics	2	2	2	1	1	1
Chemical Engineering	4	3	3	5	1	0
Civil Engineering	12	8	4	4	3	1
Electrical Engineering & Computer Science	16	7	5	20	9	5
Materials Science & Engineering	1	0	0	1	1	1
Mechanical Engineering	5	2	1	5	5	3
Nuclear Engineering	3	2	1	3	2	1
Ocean Engineering	1	1	1	0	0	0
	<u>44</u>	<u>25</u>	<u>17</u>	<u>39</u>	<u>22</u>	<u>12</u>
<u>Humanities and Social Science</u>						
Economics	13	3	2	4	0	0
Linguistics & Philosophy	0	0	0	0	0	0
Political Science	2	1	1	10	6	1
Psychology	2	0	0	4	2	0
	<u>17</u>	<u>4</u>	<u>3</u>	<u>18</u>	<u>8</u>	<u>1</u>
<u>Sloan School of Management</u>						
	29	11	5	38	18	4
<u>Science</u>						
Biology	9	1	1	3	3	1
Chemistry	4	3	1	6	3	3
Earth & Planetary Sciences	1	1	0	2	0	0
Interdisciplinary Science	0	0	0	1	0	0
Mathematics	3	0	0	0	0	0
Meteorology	0	0	0	0	0	0
Nutrition & Food Science	5	2	1	1	1	1
Physics	9	2	1	15	10	5
HST	-	-	-	1	0	0
	<u>31</u>	<u>9</u>	<u>4</u>	<u>29</u>	<u>17</u>	<u>10</u>
TOTALS	196	73	52	195	92	45

TABLE XV
TRENDS IN MINORITY GRADUATE STUDENT ENROLLMENT AT MIT

Minority Graduate Student Enrollment

1972-73 to 1979-80

<u>School</u>	<u>1972</u>	<u>1973</u>	<u>1974</u>	<u>1975</u>	<u>1976</u>	<u>1977</u>	<u>1978</u>	<u>1979</u>
Architecture & Planning	40	41	41	50	59	44	46	45
Engineering	19	25	38	38	44	40	44	47
Humanities & Social Science	22	28	34	30	27	21	16	9
Management	10	9	10	9	17	20	13	9
Science	17	18	28	28	31	32	28	34
Total Minority	108	121	151	155	178	157	147	144
Total All Graduate Students	3,328	3,358	3,468	3,603	3,774	3,824	3,944	4,146

Black Graduate Student Enrollment

1972-73 to 1979-80

<u>School</u>	<u>1972</u>	<u>1973</u>	<u>1974</u>	<u>1975</u>	<u>1976</u>	<u>1977</u>	<u>1978</u>	<u>1979</u>
Architecture & Planning	34	33	34	39	45	34	32	34
Engineering	10	16	26	25	25	25	33	33
Humanities & Social Science	19	24	31	26	23	17	14	8
Management	9	8	10	8	13	17	12	9
Science	15	16	22	21	24	21	20	20
Total	87	97	123	119	130	114	111	104

Minority & Black Graduate Student Enrollment as Percent of Total Graduate Enrollment

1970-71 to 1979-80

<u>Year</u>	<u>Total Graduate Enrollment</u>	<u>Minority Graduate Enrollment</u>	<u>Percent</u>	<u>Black Graduate Enrollment</u>	<u>Percent</u>
1970-71	3,296	-	-	55	1.6%
1971-72	3,250	-	-	88	2.7%
1972-73	3,328	108	3.2%	87	2.6%
1973-74	3,358	121	3.6%	97	2.9%
1974-75	3,468	151	4.3%	123	3.5%
1975-76	3,603	155	4.3%	119	3.3%
1976-77	3,774	178	4.7%	130	3.4%
1977-78	3,824	157	4.1%	114	3.0%
1978-79	3,944	148	3.7%	111	2.8%
1979-80	4,146	144	3.5%	104	2.5%

Medical Department

During this last year, we have started to advance the development and maturation of those programs which will be particularly important to our function in the new building. That structure is growing visibly (we are at the exciting stage of construction which demonstrates progress weekly) and there is barely more than a year before we move in!

A meeting of the Corporation Visiting Committee to the Medical Department on November 30, 1979, provided an opportunity to present a summary of many of the programs in the Department -- some ongoing, some evolving, and some being initiated. A concern expressed by members of the Committee has also been heard in several other settings: There is insufficient knowledge in the community we serve of the activities and resources available in the Medical Department.

Although the level of utilization of the Department's services continues high and is increasing, we encountered expressions of this insufficiency of information in conversations and meetings with students, groups of employee supervisors, members of women's groups, people in the Dean's office, representatives of MIT's black community, and others. It is clear that our efforts to provide information, although vigorous, have not been sufficient.

To address this problem, three avenues of activity are identified:

- 1) Written communications will be continued and sharpened in focus. A "Student Guide to the Medical Department" will be ready for distribution in the fall; a "Guide to Obstetrical Services" will soon be returned from the printer; redistribution of the information already available will be undertaken.
- 2) Presentations of programs and lectures will be increased.
- 3) Further opportunities to meet with groups within the community are being developed.

The Health Surveillance program has been fairly launched. Not unexpectedly, problems in the mechanics of the program surfaced soon after its initiation. Because of these factors, the utilization of this resource has not been as great as anticipated. Careful evaluation of the program will continue; significant data should become available during this next year.

As noted in the last report, pre-employment health screening was discontinued on July 1, 1979. Although not all of them have accepted the invitation, new employees are asked to come to the Department soon after employment to have the tuberculin skin test that is required, as well as a blood pressure check. We hope, by this means, to introduce new patients to the Department in a friendly and helpful way, free of concern that the Department may represent a barrier to employment. The reduction in costs associated with the discontinuation of pre-employment evaluations is already being eroded by the increase in periodic evaluations required of employees working in certain settings or with certain materials. This will doubtless continue to increase.

Nurse Practitioners and Physicians Assistants have continued to use our system of computer-audited checklists in the care of patients with a range of acute problems. Last year, our experience with more than 15,000 patient visits was reported at the annual meetings of the American College Health Association and the Group Health Association of America. The presentation at the latter meeting by Dr. Michael Kane and Sally Zinno stimulated much interest, and was further reported in the Group Health Association News and other periodicals.

One of the purposes for the development of this system was to satisfy the requirement that nurse practitioners must work with "guidelines for practice." These requirements have finally been further clarified with the issuance, in February 1980, of regulations governing the practice of nurse practitioners, who are now required, in addition, to have completed a formal education program and to be certified by passing an examination administered on a national basis by the American Nursing Association. Five of our nurse practitioners are already certified; all of the others will be taking the certification examination when it is next given (November 1980).

In addition to implementing the protocols ("guidelines") with which our non-physician providers work, the checklist system has proved to be a very valuable source of data for the Quality Assessment Committee. This group, now chaired by Dr. Samuel Stein, seeks to integrate the many activities in the Department that have to do with quality-assessment, as well as to carry out audits of the functions of the Department. We are currently seeking a new staff member to provide the special support that this committee needs.

Despite its many advantages, however, it remains clear that the checklist system is regarded negatively by most of the people who use it. A study of checklist utilization conducted by a graduate student confirmed this impression. It is not perceived as a helpful educational tool, but rather as a means of identifying errors (which, of course, is one of its functions). In recognition of this, the Department is developing an educational program for nurses which will, it is hoped, counterbalance to some extent the perceived unpleasantness of using the checklists. The program will also provide some of the formal educational credits required by the new regulations.

In the new building, internal medicine services, which account for most of the primary care, will be provided by groups of professionals (physicians with nurse practitioners and physicians assistants) working in modules which we have called "clusters." Interactions among these people will be facilitated. This provides an exciting opportunity for the development of new modes of practicing medicine. Much remains to be done, however, in planning for this; "cluster planning," then, will be actively pursued during this coming year, with the vision of the development of teams for health care delivery still clearly before us.

We have continued to function as a medical specialty training resource for primary care residents at the Mount Auburn Hospital. In addition to the ongoing programs in dermatology and rheumatology, we were able to offer participation in the pediatric and gynecology services this last year. Next year, we will further expand our participation in the formal primary care training program; a medical resident will join the Department on a half-time basis.

We have continued our efforts to stay involved with the care of our patients who are admitted to hospitals under the treatment of physicians outside the Department. Pauline Jones has been providing a linkage with these patients. She has had the advantage of working with the Liaison Committee which provides medical, psychiatric, and insurance expertise in meeting patients' needs. Mrs. Jones has established relationships with the Glenside, McLean, and Charles River hospitals, and continues as a member of the staff at the Mount Auburn Hospital. The participation of members of the Dean's office in these activities has been exceptionally valuable. Accomplishments of this program have included facilitation of contacts between hospitalized students and their faculty advisors, encouragement of early transfer back to the MIT Infirmary and the care of the primary physician, freer interchange between social workers at the hospital and those in the Department, arrangement of appropriate transportation for the patients, and identification or provision of consultants needed for the care of the patient.

Mrs. Jones and the members of the Disaster Plan Committee have developed a disaster plan for the Department. It will be tested with a mock disaster (the Department's first) on July 2, 1980. Integration of the activities of Department members with those of the Campus Patrol, Safety Office, Environmental Medical Service, and others -- including the City of Cambridge and hospitals in Cambridge and Boston -- needs to be practiced. We also plan an unannounced test of the system during the summer.

As mentioned earlier, we are concerned at what is seen as insufficient information about the Department in the MIT community. Similarly, we feel the need for more information about patient attitudes toward the Department. With the help of two students (David Plotkin, an MIT undergraduate; and Jill Silverman from the Harvard School of Public Health), a questionnaire has been developed and distributed to a weighted sample of the MIT community. Returns of about 50 percent were hoped for and, it appears, achieved. The results are currently being analyzed. We plan to repeat the survey periodically.

A group of women students took the initiative in expressing their concerns about the gynecology service and communicating them to the Medical Director. We have had three meetings on the subject which have been very helpful. The participation of Dean Holliday Heine and Professor Lisa Steiner, chairman of the Medical Advisory Board, has been central to the occurrence and positive nature of these meetings.

Each year, outside professional activities are reported by each member of the staff. The following is a listing of organizations for which Department staff members provide special advisory or consultative services, aside from membership in societies or in specific areas of professional competence:

American Civil Liberties Union	Haverford College
American Cancer Society	International Childbirth Education Association
American College Health Association	Massachusetts Public Health Association
American Heart Association, Greater Boston Division	Mount Auburn Hospital
American Red Cross	Mystic Valley Mental Health Center
Board of Registration in Nursing	National High Blood Pressure Coordinating Committee
Cambridge Health Policy Board	National Institutes of Health
Cambridgeport Problem Center	New England College of Optometry
Food & Drug Administration	Policy and Advisory Committee for Child Abuse and Neglect
Harvard Community Health Plan	South End Community Health Center
Harvard University School of Public Health	

In addition, the staff has participated in teaching at:

Boston University School of Medicine	Harvard University School of Public Health
Harvard Medical School and its various teaching hospitals	Johns Hopkins University
	New England Medical Center

The staff also includes members of the editorial boards of several professional journals.

Level of Activity

Last year saw both a continued increase in the total number of visits to the Department and a decrease in the number of visits made by students. The overall total (120,333) is up by 2.5 percent from the preceding year; if dental visits are excluded, the increment is 3.5 percent. Increased utilization is seen in internal medicine (4.8 percent), pediatrics (19 percent), orthopedics (8.3 percent), gynecology (12 percent) and several other specialties. A substantial decrease (9 percent) was experienced in the nurse practitioner area, where students comprise a large proportion of total visits. The number of student visits fell by 13.4 percent in this area; they made up 47.7 percent of the total visits to nurse practitioners last year as contrasted with almost 50 percent the preceding year.

A fall-off in student visits is also seen in surgery and dermatology. Visits to internal medicine were up slightly; the gynecology service experienced a substantial increase in student visits (8.4 percent); there was little change in student utilization of other services, including the Off-hours Clinic. Overall, students made 1,619 fewer visits last year, a decrease of 4.2 percent.

Our students still make substantial use of the Department, averaging 4.3 visits per student per year (excluding dental visits). Reasons for the decrease are probably multiple and, for the most part, not well understood. Our experience is not unique; a decrease in student utilization of health services has been noted widely, perhaps reflecting a change in social factors more than medical ones. In any case, we want our students to know more about what we have to offer. We plan to address this issue with some vigor this coming year.

Our Health Plan members continue to use the Department quite heavily, averaging well over six visits per member per year. They made about 40 percent of the total number of visits (excluding dental) last year, demonstrating an increment both in the number of visits and the percentage of the total.

Utilization of the Infirmary has increased. Both the total number of admissions (632) and the number of patients days (2,771) are higher. Within those totals, the distribution between inpatient admissions and observation-unit admissions has shifted; the former have increased by 50, the latter decreased by 83. The following table may help to elucidate the shift.

Medical Department

	<u>FY 1980</u>	<u>FY 1979</u>	<u>FY 1978</u>
Inpatient days	2,550	1,823	1,835
Observation admissions	221	304	359
Total	2,771	2,127	2,194

The change in the relationship between inpatient and observation admissions reflects a change in the rules governing observation status. These were effected in order to assure prompt evaluation of patients and to avoid some of the ambiguities surrounding the shift from observation to full inpatient status. They seem to be working well.

The Off-hours Clinic also experienced an increase in utilization (247 visits; 4 percent). Student utilization was essentially unchanged (48 fewer visits).

Despite last year's experience with students, it is reasonable to expect further increases in utilization of the Department. This is predicated on continued growth of the Health Plan, continued increases in utilization of the Infirmary, and better understanding of the patterns of student use.

Staff Changes

Several of the following appointments represent a change in status of Infirmary inpatient nurses to staff level.

Once again, the Department sustains a loss in the retirement of several valued colleagues and friends. Drs. George Bottomley and John Homans have decided to listen to the siren-song of the hunting and fishing seasons and the golf course; Fred Smith, sanitation consultant for decades after his official "retirement" from work with the City of Cambridge, has decided really to do it this time; and Dr. Samuel D. Clark, Associate Medical Director, Emeritus, from whose skills and wisdom we have benefited since his own official "retirement" five years ago, has reached the age when neither he nor we have any further choice.

APPOINTMENTS

Joyce Aijala, R.N. Inpatient Nurse	Elaine Dors, R.N.P. Nurse Practitioner	Geoffrey Linburn, M.D. Psychiatrist
Joel Ackerman Microbiologist, DLAM	Elaine Drew, R.N. Nurse, Off-hours Clinic	Elizabeth Matteson, R.N. Inpatient Nurse
Christine Anderson Medical Technologist, DLAM	William Franklin, M.D. Allergist	John McKeigue, M.D. Otolaryngologist
Joyce Arlington, R.N.P. Nurse Practitioner	Ronald Geiger, M.D. Orthopedic Surgeon	Winslow Poor Manager, DLAM animal facilities
Bruce J. Biller, M.D. Physician	Fruma Ginsburgh, M.D. Obstetrician/Gynecologist	David Reisen, M.D. Psychiatrist
Joyce Bishop, P.A. Physician Assistant	Joy Ann Kay, R.N. Inpatient Nurse	Margaret Ross, M.D. Psychiatrist
Marx Bowens, M.D. Neurosurgeon	Louis Kertzman Sanitary Consultant	Robert Russell, R.N. Inpatient Nurse
John Brandt, M.D. Psychiatrist	John Kurkjian, M.D. Otolaryngologist	Clare Sellig, R.N. Inpatient Nurse
Anita Darveau, R.N. Inpatient Nurse	Patrick Lamin, R.N. Inpatient Nurse	Cynthia Stevens, D.D.S. Director of Dental Service
	Carolyn Leonard, R.N. Inpatient Nurse	

Vice President and Dean of the Graduate School

Joel Watson
Administrative Officer,
DLAM

Warnie Webster, M.D.
Postdoctoral Fellow,
Psychiatry Service

Gerald Zuriff, M.D.
Psychiatrist

RETIREMENTS

George Bottomley, M.D.
Surgeon

John Homans, M.D.
Physician

Fred Smith
Sanitation Consultant

RESIGNATIONS

Joyce Bishop, P.A.
Physician Assistant

Christine Bridges, R.N.
Inpatient Nurse

Monique Cantin, R.N.P.
Supervisor of Nurses,
Off-hours Clinic

Valentina Donahue, M.D.
Obstetrician/Gynecologist

Barbara Hugh, R.N.P.
Nurse Practitioner

Ruby Jackson, M.D.
Obstetrician/Gynecologist

John Kurkjian, M.D.
Otolaryngologist

Catherine Marin, R.N.
Inpatient Nurse

Steven Nigro
Administrative Officer,
DLAM

Cora Origeneza, R.N.
Inpatient Nurse

Robert Stewart, M.D.
Physician

Susan Wicks, R.N.P.
Nurse Practitioner

PROMOTIONS

Janet Beyer, R.N.
Supervisor of Nurses,
Outpatient and Off-hours
Clinic

Ronald Fleming, A.C.S.W.
Chief, Social Work Service

Michael A. Kane, M.D.
Associate Medical Director

Dental Service

The Department was extremely fortunate in identifying Dr. Cynthia M. Stevens as the new Chief of the Dental Service. Under her able leadership, the goals and directions of the Service have been redefined. Careful attention has been paid to communication with patients, revising the patient record system, and improving the emergency system. Transition to a service primarily oriented toward providing dental care for students and their families, with stress on preventive dentistry, is now occurring.

Obstetrics and Gynecology

This service continues to be busy and hard-working. It experienced an increase of 12 percent in utilization, including a substantial increase (8.4 percent) in visits made by students.

The number of obstetrical deliveries rose to 153. Of these, 26 were attended by Barbara Merrifield, our nurse-midwife. The long-anticipated offering of an alternative mode of delivery for some of our obstetrical patients is particularly welcome.

In mid-July, Dr. Laurent Delli-Bovi will be joining Drs. Charles Eades and Fruma Ginsburgh to provide needed additional services for the growing number of obstetrical and gynecological patients.

Psychiatry Service

Dr. Merton J. Kahne, Psychiatrist-in-Chief, offers the following report:

Last year the full impact of economic stringencies, energy cutbacks, and international political complexities made themselves felt throughout the MIT community. Probably the single most compelling difficulty on the horizon will be effectively helping new graduate students and their families cope with unremitting shortages in housing, shrinking economic assistance, increasing costs of living and education, and all the complicated tensions, confusions, irritations, and other interpersonal troubles these entrain. Fortunately, the entire community has been alerted to their special difficulties and has responded helpfully in countless ways.

Medical Department

There has been a continuing rise both in the number of persons consulting the service (8.1 percent) and in the number of visits (23 percent). Most noticeably, requests for help with children of Health Plan members have been more frequent, both by referral from the internists and pediatricians, and through direct inquiry from parents. Drs. Lora Heims Tessman and Lois Eichler, who shoulder the main responsibility for meeting our child care needs, have become very much involved in working with school teachers and others outside MIT as consultants and supervisors of the complicated therapeutic/educational programs that effective child care entails. All of us have found ourselves doing parent guidance and couple counseling related directly to responding to calls for help for troubled children.

To our great delight, the number of patient days in hospital dropped to less than half of last year's figure, largely due to the absence of any truly long-term hospitalization. It seems clear that our improved liaison with outside hospital staff, via important assistance from Ms. Jones and Dr. Wade Rockwood, and the concentrated effort of all our staff to keep hospitalization to a minimum, has been effective.

Some part of the rise in service consultations is related directly to the effectiveness of the Institute Personal Assistance Program, spearheaded by Ronald Fleming of the Social Work Service.

The extended-care program constitutes about 15 percent of those Health Plan members who require more extended definitive psychotherapy. Internally, both the professional and administrative personnel report improved ease of placement and referral, and more rapid cementing of therapeutic relationships. When offered alternatives, patients generally opt for our in-house services as against outside referrals. Preliminary estimates suggest that average length of therapy is slightly less than with outside placements, despite the fact that some of our more complex cases have been referred to this program. Drs. Geoffrey Linburn, David Reisen, and John Brandt are now with us, helping make this extended therapy program an effective enhancement to our other clinical services.

For the first time in years, turnover in our office personnel was very light. To the distress of all of us, Sister Elizabeth Iverson, artist, seamstress extraordinaire, and staff humorist left to take up work in another city. Julie Roberts arrived in June to help keep the secretarial service maintaining its cheerful responsiveness to both our clientele and our professional staff. In March, Carole Teague joined the staff to fill a long-needed gap in our office procedures. Lastly, to our delight, Stephani Nur joined with Mark Colby in marriage. Fortunately for all of us, she has decided to continue to hold down that complex juggling act we euphemistically call Psychiatry Service secretary.

There were 62 patients admitted to the Infirmary last year for psychiatric problems, for a total of 217 patient days. In addition, there were 225 individuals from 50 foreign nations who visited the service.

Social Work Service

In recognition of his outstanding accomplishments since joining this Department and in acknowledgement of his clearly-demonstrated leadership qualities, Ronald W. Fleming was promoted to Chief, Social Work Service. He offers the following report:

The Social Work Service continues to serve a variety of organizational, group, and individual needs within the MIT community. It attempts to balance its efforts between the needs of individual patients and the community as a whole. Meeting the needs of persons with special problems has been and continues to be a particular focus.

Among the special need groups served this year are: minority students -- through minority student discussion group; foreign wives -- through the wives group; parents of teenagers -- special time-limited group offered conjointly by the health educators and the Family Service Association of America (FSAA); working parents of infants -- offered conjointly with the health educators and FSAA; persons with alcohol problems -- through the alcohol support group; and troubled employees -- through the Institute Personal Assistance Program (IPAP).

In an effort to help enhance the quality of life at MIT, whether it be for work or study, members of the Social Work Service staff have been involved in a number of planning and consulting

activities. Staff have participated in United Fund activities, the Technology Children's Center, minority graduate student orientation, the Women's Advisory Group, Women Student Coordinators' Advisory Group, the Privacy Committee, and the IPAP.

Clinical activity with individuals, couples, and families in need has increased in the past year. Health Plan members account for 40 percent of all visits; students 21 percent; and faculty, staff, and employees, 31 percent. The overall volume of activity has increased markedly from two years ago due to the combined influences of increased service demand, the continuing effect of the Personal Assistance Program, and the presence of a student intern. In terms of clinical activity, the IPAP has now experienced over 150 referrals since its inception. The alcohol support group, sponsored by the IPAP, has now been involved with 26 persons and has increased its average participation by 25 percent since beginning in October.

The IPAP was featured in an article in the February 1980 issue of the *Journal of the American College Health Association*, coauthored by Alfred Koumans, M.D., of the Psychiatry Service.

The Social Work Service is involved in several other activities designed to ease patients' access to care and improve upon the coordination of treatment. To accomplish this, we are meeting with the Social Service staffs of hospitals affiliated with this Department.

The Social Work Service was able to host a social work intern this year, a second year M.S.W. student from Simmons College, Stefan Krug. Mr. Krug performed well and enabled the Service to increase its outreach capability and level of clinical activity. We hope to continue our liaison with social work interns from local universities when space allows in the new building.

We welcome to our Social Work Service our new secretary, Ruth Lambiase, who serves us well both as secretary and as an assistant.

Health Education and Information

This service continues at a high level of activity. Last year, the following programs were offered:

Weight Control: Programs of 10 sessions, each preceded by an introductory orientation session, were offered continually throughout the year. One program was conducted at Lincoln Laboratory. Follow-up sessions were offered once each month for all program participants. Two Peter Bent Brigham nutritionists and an MIT health educator provide leadership. Total number of participants was 90.

Smoking Cessation: Two programs were held. The first of these was a five-day program conducted on campus by the New England Memorial Hospital; the second was led by an MIT health educator and included follow-up sessions. Total number of participants was 30.

Prenatal and Parent Group Meetings: Twenty-four meetings were held with an average attendance of 24 to 30.

Lamaze Childbirth Review Class: Twelve monthly sessions were held with four to eight couples participating in each session.

How to Communicate Better with Your Teenager: This program was co-sponsored by the Medical Department Health Education Service, Social Work Service, and the Family Service Association of Greater Boston. Eight individuals participated in this six-session workshop.

Workshop for Working Parents of Infants: This six-session workshop was designed for parents of infants in families where the mother had returned, or was planning to return to employment. Leadership was provided by Family Service Association, the Medical Department Social Work Service and Health Education Service. Fourteen parents attended.

In addition, the Department supported and participated in a Stress Management Workshop, sponsored by the Women's Forum. This all-day activity attracted 150 participants.

Medical Department

The following lectures were offered:

Reducing Your Risk of Cardiovascular Disease: One session on campus - 40 participants.
One session at Lincoln Laboratory - 75 participants.

Independent Activities Period:

Contraceptive Techniques - 60 participants.	Gynecological Exam - 12 participants.
Childbirth in America - 40 participants.	Role of the Nurse Practitioner - 10 participants.
Sports Medicine (2 sessions) - 90 participants.	Outdoors Medicine (6 sessions) - 70 participants.
Biological Research Safety - 20 participants.	Reducing Your Risk of Cardiovascular Disease (2 sessions) - 30 participants.
Periodontal Disease - 20 participants.	

This service also has an important patient advocacy function. Last year, there were 285 contacts with patients around issues involving complaints, perceived grievances, requests for further information, and even a few compliments. In addition, two to four inquiries are received each day requesting health information.

The great patient interest in health education and its possible connection with disease prevention continues to generate many demands on this service. This coming year, Dr. Bruce Biller will be working with Constance Bean and Iris Ponzetti in an effort to respond to these demands, while providing some definition to the scope and focus of the activities offered.

Environmental Medical Service

Dr. Melvin H. Chalfen, Assistant Medical Director and Physician-in-Charge, Environmental Medical Service (EMS), offers the following report:

Public concern about environmental risks in the United States continues to increase, especially in regard to disposal and transportation of toxic substances. The EMS has had particular concerns this year in the matter of radioactive waste disposal, as the trend toward reduction in the number of waste sites continues.

In October 1979, the Hanford, Washington burial site for radioactive waste was closed for a few weeks. At the time, it was the only site available for such disposal. Fortunately, it was re-opened; but it may close again. Solutions to the problem of radioactive waste disposal are now being sought in the encouragement of regional disposal sites and in attempts to decrease the volume of such waste. Similar efforts are being made in regard to hazardous wastes in general. Both traditional methods of waste disposal and newer, more creative and ingenious methods of disposal are being examined. At present there is not, unfortunately, any one specific solution within grasp. The decreasing availability of sites and increasing costs provide great motivation to seek answers both within and outside the Institute.

During this spring an accident in nearby Somerville led to the rupture of a tank car containing phosphorus trichloride. This material, in contact with moisture in air and with water, formed a cloud of toxic material which blew briefly in the direction of the MIT residential towers. Evacuation was considered, but plans were cancelled with the advice of Richard Chamberlin of the Industrial Hygiene Office and the wind projections of the MIT Meteorology Department. The incident, however, has served as a reminder of the need for constant review of disaster plans at the Institute in coordination with the community.

Another concern also noted in previous years but now more pressing is the tendency for regulatory groups to include "medical surveillance" as compulsory parts of contracts and regulations. These well intentioned efforts, however, in my opinion, are seldom capable of achieving the aims sought. There are few tests which are specific in terms of exposure to chemicals. Physical examinations as a group produce such a low yield of positive results that the costs become prohibitive, and, in addition, a false sense of reassurance is given. There are, of course, a few exceptions where specific testing is possible. In general, the greatest protection for the person working with potentially hazardous materials is containment of the hazard through engineering controls, assessment and advice on work processes and operations, and occasionally the provision of appropriate personal devices such as respirators.

We have continued the programs of monitoring people working with asbestos, beryllium, certain carcinogens, and recombinant DNA, as well as programs for hearing protection. Radiation protection continues as in the past with attention to achieving the lowest possible exposure.

During the year we have initiated with the Pediatric Department an in-house capacity for lead screening in children.

The Radiation Protection Office (RPO) has continued under the able leadership of Murray Bolton as Acting Head while we continue our search for a permanent head. The Radiation Protection Office has had the brunt of the pressures from disposal of radioactive waste as well as absorbing the continual increase in their other service activities. Use of the Central Radioisotope Lab continues to increase. Training programs also have increased, and, in addition, RPO members have presented health physics information in local high schools as part of the MIT Project on Work in Technology and Science.

The Reactor Radiation Protection Office worked with 35 MIT people and 85 Northeastern University students at the Reactor. Testing and monitoring continues to increase in amount and sophistication.

The Linear Accelerator Radiation Protection Office has again been busy with designing shielding and monitoring operations for new construction at the Accelerator. The 24-hour per day and 14- to 21-day operations continue.

The Industrial Hygiene Office initiated a change in the Campus Patrol training sessions from lectures to an on-site EMS orientation in our labs, which proved very popular and resulted in similar sessions for Lincoln Lab Safety Coordinators. The group continues to note increased requests for advice and service.

The Biohazard Assessment Office (BAO) has continued development of monitoring programs in the MIT laboratories, orientation of workers, collaborative projects with academic departments, and, at the request of the Japanese government, outlined the BAO experiences with recombinant DNA technology safeguards and regulations. Dr. Liberman worked with Johns Hopkins University in developing a biological safety officer program and with the Harvard School of Public Health in a course on biohazard cabinetry.

Radioactivity Center: During this past year the contractor for the radium patient studies, the Argonne National Laboratory funded by the Department of Energy, has discontinued the examination of radium patients at the Radioactivity Center. This action left the instrumentation laboratory -- the whole-body counter and supporting electronic instruments -- without financial support. Since the whole-body counter is recognized as the best calibrated and virtually the only whole-body counter of its type in the Northeast and, therefore, a valuable resource for other departments at MIT as well as other research organizations in the area, efforts are in progress to secure support elsewhere.

Division of Laboratory Animal Medicine

Dr. James G. Fox, Director of the Division, points out that the Good Laboratory Practices Act which governs many of the research protocols at MIT has stringent requirements for the quality of animal facilities. With the renovations nearing completion, the Institute should be in compliance with those statutory requirements.

The Research Animal Diagnostic Laboratory, now completing its fourth year of operation, continues to provide substantial support for research activities at MIT and at other institutions in the area. With four recent additions, there are now 12 such outside facilities. The Laboratory is actively engaged as well in the study of infectious disease in laboratory animals, the development of animal models for the study of human disease, and several collaborative research programs.

A major function of the Laboratory continues to be the provision of clinical diagnostic expertise. Laboratory activities are integrated into a campus-wide clinical surveillance program which includes daily clinical rounds and close monitoring of all animals for signs of disease.

In this area, the Division has continued to develop and refine specific disease surveillance protocols for many animal species (primates, dogs, cats, rabbits, mice, rats, guinea pigs, hamsters, opossums, ferrets, and frogs). In addition, a program of surveillance of rodent vendors has been developed. Rodents acquired from non-approved vendors are quarantined and closely monitored before release for investigational purposes.

The Division remains active in teaching undergraduate, graduate, and veterinary students, as well as being involved in UROP. Last year, three veterinary students worked in the Division during the summer.

Research continues to be active and growing. Last year, the DLAM staff published 18 articles, produced an additional eight articles now in press, and presented eight papers as invited speakers at symposia, national meetings, and university-sponsored lectures. Dr. Fox, moreover, has been selected by the American College of Laboratory Animal Medicine to be co-editor of a three-volume work on "The Mouse in Biological Research."

MIT Health Plan

Laurence H. Bishoff, Associate Director for Administration and Chief Administrative Officer, MIT Health Plan, offers the following:

I am pleased to report that the MIT Health Plan passed another milestone this year, having enrolled its 7,000th member. On May 31st, membership stood at 7,329 persons, a net gain of 7.7 percent during last year. To achieve this membership level, 2,449 new members were enrolled. Net turnover during the year was 29 percent, consistent with the past few years' experience. Virtually the entire turnover is caused by members leaving MIT or leaving the Plan because of personal circumstances such as leaves of absence. Less than 100 employees cancelled their membership last year due to dissatisfaction.

The number of subscriber contracts grew at a rate of 10.2 percent. This rate is higher than the membership rate because there continues to be a shift to single members. By year end more than 50 percent of our contracts were with individuals. This number is in dramatic contrast to the initial projections for the MIT Health Plan which forecast a mere 25 percent of total subscription would be to individuals.

During this year also, the Harvard Community Health Plan (HCHP) was introduced at MIT. The MIT Health Plan's rate structure was generally comparable to HCHP. Nineteen subscribers transferred to HCHP during this year. By the end of the year, not quite 100 MIT personnel had enrolled with HCHP.

Two new membership programs were begun during the year. Until the advent of the first program, membership in the MIT Health Plan had ended when the member reached age 65. Now under a new plan, called MIT Health Plan 65, employees over 65 can continue their membership in coordination with Medicare coverage. The combined plan actually gives somewhat greater coverage to members than the regular MIT Health Plan benefit at a net expense of about 40 percent of the standard MIT Health Plan premium. Initially offered to those employees who remain actively employed after age 65, the Plan permits MIT and the Draper Laboratory to meet their obligations under the law by offering the same benefit options to employees over 65 as those under 65. If actual experience remains close to projected totals, we intend to expand the offering to retired employees.

Under the second new program, the MIT Health Plan is offered as an option to employees of the Harvard Community Health Plan. This program was inaugurated at the request of Harvard Plan officers who stated that some of their employees wished to join a health maintenance organization, but because of confidentiality wanted an option outside the Harvard Plan. We were glad to accommodate a sister institution as an exception to our policy of limiting services to the MIT community.

The staff has developed new marketing resources during the past year to introduce the MIT Health Plan to new employees. A new slide/talk show, special brochures, and staff talks have all been developed and refined this past year. The MIT Health Plan continues to be the program

of choice for more than 50 percent of new employees who choose one of the MIT health benefit options.

Utilization in the MIT Health Plan continues to be high. With more than six visits per member, the MIT Health Plan accounts for the heaviest per capita utilization of any program reported in the latest national health maintenance organization census. Hospital utilization continues to be expensive, amounting on a unit cost basis to more than \$400 per day and to 396 days per year per 1,000 members in the acute hospital, and 142 days in the MIT Infirmary. The number of acute hospital days is slightly under the average of 412 days for health maintenance organizations nationwide (before adjusting for special factors such as age, sex, and higher than average maternity experience). The Plan's hospital experience is also less than that of health maintenance organizations of similar age (462 days/1,000) or size (479 days/1,000).

Despite these expenses, the MIT Health Plan rates have been consolidated in the past year to a single rate structure that is competitive and financially advantageous to staff and non-staff members considering MIT health benefit options. Of course, this rate structure covers the direct and MIT indirect expenses of operating the Plan.

The MIT Health Plan remains exempt from State Licensure and is not eligible for Federal qualification. This year, however, we have participated in the formulation of a State Association of Health Maintenance Organizations, and the Plan is a member. Further efforts to address the Federal qualification issue have been reviewed this year in Washington. We are not very optimistic about becoming eligible for qualification but are actively reconsidering pressing for a legislative remedy along with the Harvard University and Yale plans, the only two other similar organizations among colleges and universities.

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	1977-78	8,712
1900-01	1,277	1939-40	3,100	1978-79	8,881
1901-02	1,415	1940-41	3,138	1979-80	9,053
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	1977	2,321	1,724
1961	1,668	1,412	1978	2,344	1,611
1962	1,748	1,763	1979	2,610	1,748
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 and Professors Emeriti*	Sr. Lecturers	Lecturers	Sr. Research Scientists	Instructors	Technical Instructors	Sr. Research Associates	Postdoctoral Associates	Research Assistants	Teaching Assistants	Instructor Grad	Total	Visiting Professors	Others ¹	
Institute Professors	10	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	2	-	
Institute Lecturers	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	
School of Architecture and Planning	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	
Architecture	12	1	-	3	12	12	-	8	2	-	2	10	-	-	5	25	-	90	2	10	
Urban Studies and Planning	9	1	-	1	15	4	-	2	2	-	1	-	-	-	9	-	14	58	5	13	
Total	21	2	-	4	27	16	-	2	10	-	3	10	-	-	14	25	14	148	7	24	
School of Engineering	2	4	-	-	2	-	2	-	1	-	-	-	-	-	-	-	-	-	11	1	3
Aeronautics and Astronautics	22	2	-	2	7	4	2	5	16	-	-	2	1	5	90	4	-	162	-	8	
Chemical Engineering	12	2	-	-	5	7	1	1	3	-	2	2	-	2	83	38	-	158	-	17	
Civil Engineering	18	1	-	-	15	11	-	4	1	-	-	-	1	2	134	21	1	209	5	14	
Electrical Engineering and Computer Science	51	10	-	3	24	16	3	16	2	-	-	1	1	1	219	89	-	436	5	21	
Materials Science and Engineering	22	1	-	1	6	5	1	-	1	-	-	3	1	10	114	20	-	185	2	27	
Mechanical Engineering	26	3	-	1	12	17	1	6	20	1	-	5	1	2	182	11	1	289	5	13	
Nuclear Engineering	12	3	-	1	4	2	1	-	1	-	-	-	1	1	88	18	-	132	1	11	
Ocean Eng	9	1	-	1	6	6	-	-	1	-	-	-	-	1	35	10	-	70	1	9	
Total	174	27	-	9	81	68	11	16	60	3	2	13	6	24	945	211	2	1,652	20	123	
School of Humanities and Social Science	-	-	-	-	2	4	-	-	2	-	1	1	-	-	-	-	-	-	16	3	8
Educational Programs	18	1	-	-	1	7	2	-	-	-	1	-	-	-	10	31	-	71	1	9	
Economics	17	1	-	-	24	22	-	1	21	-	10	12	-	-	-	2	-	110	7	4	
Humanities	13	2	-	-	1	5	-	-	-	-	-	-	-	-	13	22	4	60	-	10	
Linguistics and Philosophy	15	3	-	-	3	2	-	1	2	-	2	-	-	-	16	14	-	58	-	5	
Political Science	7	1	-	-	4	-	-	-	-	-	-	3	-	5	1	5	-	26	-	25	
Psychology	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total	76	8	-	-	35	40	2	2	25	-	14	16	-	5	40	74	4	341	11	61	
Alfred P. Sloan School of Management	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Management	28	3	-	4	17	18	3	7	3	-	-	2	1	-	41	33	2	162	8	25	

Table III Classification of Students since 1977

	1977-78					1978-79				
	2	3	4	G	Total	2	3	4	G	Total
School of Architecture and Planning										
Architecture,IV	27	44	47	194	312	34	33	47	199	313
Architecture,IV-B	1	1	2	-	4	-	2	1	-	3
Urban Studies and Planning,XI	5	9	16	148	178	12	11	10	168	201
Total	33	54	65	342	494	46	46	58	367	517
School of Engineering										
Aeronautics and Astronautics,XVI	36	41	27	177	281	52	27	42	166	287
Aeronautics and Astronautics,XVI-B(Cooperative)	3	4	3	-	10	1	4	3	-	8
Aeronautics and Astronautics,XVI-C(Internship)	-	-	-	-	-	-	6	-	-	6
Chemical Engineering,X	106	102	82	195	485	111	114	101	198	524
Chemical Engineering,X-C(Internship)	1	4	2	-	7	-	2	4	-	6
Civil Engineering,I	38	67	61	238	404	31	53	69	266	419
Civil Engineering,I-W(Woods Hole)	-	-	-	-	-	-	-	-	-	-
Electrical Engineering and Computer Science,VI	188	174	136	463	1,256	219	140	182	485	1,271
Program 1-Electrical Science and Engineering	84	99	112	-	-	59	76	110	-	-
Program 3-Computer Science and Engineering	-	45	49	49	182	-	43	48	65	207
Program 3-Computer Science and Engineering	-	20	19	-	-	-	29	22	-	-
Electrical Engineering and Computer Science,VI-A (Cooperative)	-	-	-	-	-	-	-	-	-	-
Program 1-Electrical Science and Engineering	-	45	49	49	182	-	43	48	65	207
Program 3-Computer Science and Engineering	-	20	19	-	-	-	29	22	-	-
Electrical Engineering and Computer Science,VI-W (Woods Hole)	-	-	-	1	1	-	-	-	1	1
Materials Science and Engineering,III	23	10	9	159	201	29	20	12	162	223
Materials Science and Engineering,III-A	2	4	-	-	6	3	3	4	-	10
Materials Science and Engineering,III-B(Cooperative)	6	13	6	1	26	6	17	14	-	37
Materials Science and Engineering,III-W(Woods Hole)	-	-	-	1	1	-	-	-	1	1
Mechanical Engineering,II	85	124	78	279	566	118	113	134	309	674
Mechanical Engineering,II-A	12	9	13	-	34	12	20	14	-	46
Mechanical Engineering,II-B(Internship)	2	13	13	-	28	-	11	-	-	11
Mechanical Engineering,II-T(Textile Technology)	-	-	-	3	3	-	-	-	4	4
Mechanical Engineering,II-W(Woods Hole)	-	-	-	1	1	-	-	-	1	1
Nuclear Engineering,XXII	18	14	16	172	220	16	16	7	174	213
Nuclear Engineering,XXII-A(Internship)	-	-	-	-	-	-	2	-	-	2
Ocean Engineering,XIII	14	14	10	91	129	11	15	11	86	123
Ocean Engineering,XIII-C(Cooperative)	1	4	-	-	5	-	1	2	-	3
Ocean Engineering,XIII-W(Woods Hole)	-	-	-	9	9	-	-	-	5	5
Naval Construction and Engineering,XIII-A	-	-	-	55	55	-	-	-	47	47
Shipping and Shipbuilding Management,XIII-B	-	-	-	6	6	-	-	-	5	5
Center for Advanced Engineering Study,EN	-	-	-	54	54	-	-	-	49	49
Total	619	761	636	1,954	3,970	668	712	779	2,024	4,183
School of Humanities and Social Science										
Economics,XIV	12	15	27	124	178	12	18	23	130	183
Humanities and Engineering,XXI-A	-	1	1	-	2	-	-	2	-	2
Humanities and Science,XXI-B	5	9	13	-	27	7	9	17	-	33
Linguistics and Philosophy,XXIV	2	5	4	48	59	2	2	2	48	54
Political Science,XVII	3	5	8	108	124	3	8	8	112	131
Psychology,IX	-	-	-	26	26	-	-	-	26	26
Total	22	35	53	306	416	24	37	52	316	429
Alfred P. Sloan School of Management										
Management,XV	20	36	33	345	434	36	32	46	335	449
Management Fellows,XV-A	-	-	-	65	65	-	-	-	65	65
Management-Operations Research,XV-B	-	-	-	11	11	-	-	-	23	23
Total	20	36	33	421	510	36	32	46	423	537
School of Science										
Biology,VII	43	69	68	122	302	64	59	70	123	316
Biology,VII-A	5	7	12	-	24	2	10	11	-	23
Biology,VII-B	26	17	44	-	87	11	28	24	-	63
Biology,VII-W(Woods Hole)	-	-	-	16	16	-	-	-	18	18
Chemistry,V	43	59	53	169	324	52	42	56	179	329
Earth and Planetary Sciences,XII	12	22	30	95	159	18	17	22	83	140
Earth and Planetary Sciences,XII-W(Woods Hole)	-	-	-	35	35	-	-	-	44	44
Interdisciplinary Science Program,XXV	3	6	4	12	25	3	4	9	15	31
Mathematics,XVIII	41	57	71	115	284	35	45	56	116	252
Meteorology,XIX	-	-	-	50	50	-	-	-	40	40
Meteorology,XIX-W(Woods Hole)	-	-	-	15	15	-	-	-	15	15
Nutrition and Food Science,XX	-	-	-	199	199	-	-	-	184	184
Physics,VIII	68	106	93	271	538	80	84	95	287	546
Total	241	343	375	1,099	2,058	265	289	343	1,104	2,001
Health Sciences and Technology,HST	-	-	-	43	43	-	-	-	53	53
Undesignated	140	-	-	-	140	95	-	-	-	95
First Year	1,081	-	-	-	1,081	1,066	-	-	-	1,066
Grand Total	1,081	1,075²	1,229²	1,162	4,165	8,712	1,066	1,134	1,116³	1,278³
(not included in above figures)										
Non-Institute students from Harvard	4	11	11	287	313	2	15	18	310	345
Non-Institute students from Wellesley	67	45	88	1	201	37	53	87	-	177

¹Non-Resident students²These totals include 8 students in third year, 1 in fourth year on Foreign Study; 1 student in second year, 1 in third year and 1 in fourth year on Domestic Study.³These totals include 4 students in third year and 2 in fourth year on Foreign Study; 1 student in fourth year on Domestic Study⁴These totals include 13 students in third year and 3 students in fourth year on Foreign Study; 2 students in third year on Domestic Study

2	3	1979-80 4	G	Non Res. ¹	Total	Course Number	
19	34	37	190	1	281	IV	
-	-	1	-	-	1	IV-B	
5	12	12	193	-	222	XI	
24	46	50	383	1	504	Total	
70	39	33	167	-	309	XVI	
-	1	3	-	-	4	XVI-B	
-	7	5	-	-	12	XVI-C	
105	111	110	220	-	546	X	
2	-	7	-	-	9	X-C	
32	40	68	268	-	408	I	
-	-	-	4	-	4	I-W	
224	166	151	521	-	1,332	VI	
108	71	91	-	-	-	-	
-	64	56	78	-	250	VI-A	
-	23	29	-	-	-	-	
-	-	-	1	-	1	VI-W	
29	22	23	186	-	260	III	
1	2	1	-	-	4	III-A	
8	20	14	-	-	42	III-B	
-	-	-	1	-	1	III-W	
106	115	112	357	-	690	II	
12	16	27	-	-	55	II-A	
-	23	11	-	-	34	II-B	
-	-	-	2	-	2	II-T	
-	-	-	-	-	-	II-W	
18	7	10	173	2	210	XXII	
-	3	1	-	-	4	XXII-A	
2	14	15	89	-	120	XIII	
-	-	-	-	-	-	XIII-C	
-	-	-	9	-	9	XIII-W	
-	-	-	49	-	49	XIII-A	
-	-	-	4	-	4	XIII-B	
-	-	-	55	-	55	EN	
717	744	767	2,184	2	4,414	Total	
10	14	21	127	5	177	XIV	
-	-	4	-	-	4	XXI-A	
6	11	17	-	-	34	XXI-B	
-	3	2	65	7	77	XXIV	
7	13	16	108	31	175	XVII	
-	-	-	33	2	35	IX	
23	41	60	333	45	502	Total	
23	39	42	338	1	443	XV	
-	-	-	63	-	63	XV-A	
-	-	-	23	-	23	XV-B	
23	39	42	424	1	529	Total	
39	61	64	123	-	287	VII	
6	4	20	-	-	30	VII-A	
8	12	26	-	-	46	VII-B	
-	-	-	19	-	19	VII-W	
41	52	37	191	-	321	V	
15	18	18	77	2	130	XII	
-	-	-	44	-	44	XII-W	
5	3	4	15	-	27	XXV	
34	33	51	113	4	235	XVIII	
-	-	-	42	-	42	XIX	
-	-	-	12	-	12	XIX-W	
-	-	-	192	-	192	XX	
85	79	82	274	-	520	VIII	
233	262	302	1,102	6	1,905	Total	
-	-	-	55	-	55	HST	
84					84	Undesignated	
1,060					1,060	First Year	
1,060	1,104	1,132 ⁴	1,221 ⁴	4,481	55	9,053	Grand Total
8	12	15	243	-	278	NIH	
50	67	88	-	-	205	NIW	

Table III-A Women Students by Schools, Courses and Years, 1979-80¹

COURSE	2	3	4	GRADUATE			TOTAL	
				Regular	Special	Non Resident		
School of Architecture and Planning								
Architecture,IV	8	10	4	60	6	1	89	
Urban Studies and Planning,XI	1	7	5	72	9	-	94	
Total	9	17	9	132	15	1	183	
School of Engineering								
Aeronautics and Astronautics,XVI	11	4	2	6	1	-	24	
Chemical Engineering,X	23	19	23	35	-	-	100	
Chemical Engineering,X-C	1	-	1	-	-	-	2	
Civil Engineering,I	12	10	16	20	3	-	61	
Civil Engineering,I-W(Woods Hole)	-	-	-	1	-	-	1	
Electrical Engineering and Computer Science,VI	25	11	7	41	10	-	125	
Program 1-Electrical Science and Engineering	20	6	5	-	-	-	-	
Program 3-Computer Science and Engineering	-	-	-	-	-	-	-	
Electrical Engineering and Computer Science,VI-A(Cooperative)	-	9	4	5	-	-	21	
Program 1-Electrical Science and Engineering	-	-	3	-	-	-	-	
Program 3-Computer Science and Engineering	-	-	-	-	-	-	-	
Materials Science and Engineering,III	12	8	5	26	4	-	55	
Materials Science and Engineering,III-A	-	1	1	-	-	-	2	
Materials Science and Engineering,III-B(Cooperative)	3	7	5	-	-	-	15	
Mechanical Engineering,II	19	10	13	23	4	-	69	
Mechanical Engineering,II-A	6	1	5	-	-	-	12	
Mechanical Engineering,II-B(Internship)	-	4	1	-	-	-	5	
Nuclear Engineering,XXII	3	-	-	8	-	-	11	
Nuclear Engineering,XXII-A(Internship)	-	1	-	-	-	-	1	
Ocean Engineering,XIII	1	-	-	3	-	-	4	
Center for Advanced Engineering Study,EN	-	-	-	-	-	4	4	
Total	136	91	92	158	26	-	513	
School of Humanities and Social Science								
Economics,XIV	2	2	1	18	1	2	26	
Humanities and Engineering,XXI-A	-	-	1	-	-	-	1	
Humanities and Science,XXI-B	2	1	7	-	-	-	10	
Linguistics and Philosophy,XXIV	-	1	-	23	4	4	32	
Political Science,XVII	-	3	2	32	2	10	39	
Psychology,IX	-	-	-	11	-	1	12	
Total	4	7	11	84	7	17	130	
Alfred P. Sloan School of Management								
Management,XV	5	9	14	62	5	1	96	
Management-Fellows,XV-A	-	-	-	7	1	-	8	
Management-Operations Research,XV-B	-	-	-	6	-	-	6	
Total	5	9	14	75	6	1	110	
School of Science								
Biology,VII	16	14	21	34	3	-	88	
Biology,VII-A	3	2	6	-	-	-	11	
Biology,VII-B	5	1	15	-	-	-	21	
Biology,VII-W(Woods Hole)	-	-	-	4	-	-	4	
Chemistry,V	7	13	11	30	1	-	62	
Earth and Planetary Sciences,XII	10	5	3	11	-	-	29	
Earth and Planetary Sciences,XII-W(Woods Hole)	-	-	-	14	-	-	14	
Interdisciplinary Science Program,XXV	2	-	1	10	-	-	13	
Mathematics,XVIII	9	5	6	16	-	2	38	
Meteorology,XIX	-	-	-	1	-	-	1	
Meteorology,XIX-W(Woods Hole)	-	-	-	3	-	-	3	
Nutrition and Food Science,XX	-	-	-	62	8	-	70	
Physics,VIII	7	9	5	20	2	-	43	
Total	59	49	68	205	14	2	397	
Health Sciences and Technology,HST	-	-	-	1	5	-	6	
Undesignated	19						19	
First Year	207						207	
Grand Total	207	232	173	194	665	73	21	1,565 ²

¹Also included in Table III²Total undergraduate women 806, 11 special undergraduate women are included.

Table III-B Special Students by Schools, Courses and Years, 1979-80¹

COURSE	2	3	4	6	Total
School of Architecture and Planning					
Architecture,IV	-	1	-	9	10
Urban Studies and Planning,XI	1	-	-	32	33
Total	1	1	-	41	43
School of Engineering					
Aeronautics and Astronautics,XVI	-	-	-	16	16
Chemical Engineering,X	-	-	-	5	5
Civil Engineering,I	-	-	2	20	22
Electrical Engineering and Computer Science,VI, VI-1, VI-3, VI-A	1	4	1	67	73
Materials Science and Engineering,III	-	-	-	11	11
Mechanical Engineering,II	3	-	-	23	26
Nuclear Engineering,XXII	-	-	-	3	3
Ocean Engineering,XIII	-	-	-	8	8
Center for Advanced Engineering Study,EN	-	-	-	55	55
Total	4	4	3	208	219
School of Humanities and Social Science					
Economics,XIV	-	-	-	4	4
Humanities and Science,XXI-B	-	-	2	-	2
Linguistics and Philosophy,XXIV	-	-	-	5	5
Political Science,XVII	-	-	-	10	10
Psychology,IX	-	-	-	1	1
Total	-	-	2	20	22
Alfred P. Sloan School of Management					
Management,XV, XV-A	-	-	-	34	34
School of Science					
Biology,VII, VII-A, VII-B	1	-	-	12	13
Chemistry,V	-	-	2	4	6
Earth and Planetary Sciences,XII	1	-	-	1	2
Mathematics,XVIII	2	1	5	4	12
Meteorology,XIX	-	-	-	1	1
Nutrition and Food Science,XX	-	-	-	13	13
Physics,VIII	-	-	-	6	6
Total	4	1	7	41	53
Health Sciences and Technology,HST	-	-	-	46	46
Undesignated	12				12
Grand Total	21	6	12	390	429

¹Included also in Table III

Table IV Continued, Former, and New Students

	1975-76	1976-77	1977-78	1978-79	1979-80
Continued Students					
Undergraduate and graduate students registered at the end of the last academic year (including special students).	5,747	5,980	6,055	6,122	6,260
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).	227	272	271	311	353
Undergraduate students who enrolled for the first time since secondary school (excluding special students).	1,156	1,042	1,073	1,055	1,055
Undergraduate students who enrolled for the first time at the Institute and who transferred from another collegiate institution (excluding special students).	130	134	124	120	105
Graduate students who enrolled for the first time at the Institute (excluding special students).	935	958	968	1,025	1,011
Special undergraduate and graduate students with no previous Institute registration.	287	211	221	248	269
	8,482	8,597	8,712	8,881	9,053

Table V Regular Students from Other Colleges and Graduates of M.I.T.
Classified by Schools and Courses 1979-80

	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)	12	150	31
Urban Studies and Planning (XI)	4	145	16
Total	16	295	47
School of Engineering			
Aeronautics and Astronautics (XVI,XVI-B)	13	116	35
Chemical Engineering (X,X-C)	23	179	36
Civil Engineering (I)	15	221	31
Electrical Engineering and Computer Science (VI,VI-1,VI-3,VI-A,VI-W)	104	281	252
Materials Science and Engineering (III,III-A,III-B,III-W)	2	147	29
Mechanical Engineering (II,II-A,II-B,II-T,II-W)	30	272	64
Nuclear Engineering (XXII,XXII-A)	5	143	27
Ocean Engineering (XIII,XIII-A,XIII-B,XIII-C,XIII-W)	8	127	16
Total	200	1,486	490
School of Humanities and Social Science			
Economics (XIV)	4	118	5
Humanities and Engineering or Science (XXI-A,XXI-B)	1	-	-
Linguistics and Philosophy (XXIV)	-	52	8
Political Science (XVII)	2	91	7
Psychology (IX)	-	27	5
Total	7	288	25
Alfred P. Sloan School of Management			
Management (XV,XV-A,XV-B)	4	342	48
School of Science			
Biology (VII,VII-A,VII-B,VII-W)	10	118	12
Chemistry (V)	10	186	1
Earth and Planetary Sciences (XII,XII-W)	5	102	18
Interdisciplinary Science Program (XXV)	2	12	3
Mathematics (XVIII)	16	95	14
Meteorology (XIX,XIX-W)	-	51	2
Nutrition and Food Science (XX)	-	141	38
Physics (VIII)	40	210	58
Total	83	915	146
Health Sciences and Technology (HST)	-	6	3
Non-Resident	-	51	4
Undesignated	2		
First Year	2		
Grand Total	314	3,383	763

Table VI List of Colleges and Universities with Number of Graduates
Entering the Institute as Regular Students¹

Alabama, University of	3	Friends World College	1
Alaska, University of	1	General Motors Institute	6
Albany, University of	1	George Washington University	2
Albion College	1	Georgia, University of	2
Alfred University	2	Georgia Institute of Technology	4
American University	2	Georgia State University	1
Amherst College	1	Goddard College	1
Antioch College	2	Hamilton College	3
Arizona, University of	2	Hampshire College	1
Arizona State University	2	Hampton Institute	1
Arkansas, University of, Fayetteville	1	Harvard University	26
Auburn University	1	Harvey Mudd College	1
Beloit College	1	Haverford College	1
Bentley College	1	Hawaii, University of	1
Boston College	4	Holy Cross, College of the	1
Boston University	13	Houston, University of	1
Bowdoin College	3	Illinois, University of, Chicago Circle	4
Bowling Green State University	1	Illinois, University of, Urbana-Champaign	5
Brandeis University	4	Illinois Institute of Technology	1
Brigham Young University	4	Illinois State University	10
Brown University	10	Indiana University, Bloomington	3
Bryn Mawr College	2	Iowa, University of	1
Bucknell University	1	Iowa State University of Science and Technology	2
California, University of, Berkeley	29	Johns Hopkins University	4
California, University of, Davis	5	Kalamazoo College	1
California, University of, Irvine	2	Kansas, University of	4
California, University of, Los Angeles	12	Kansas City Arts Institute	1
California, University of, Riverside	3	Kent State University	1
California, University of, San Diego	3	Lafayette College	1
California, University of, Santa Barbara	3	Lehigh University	5
California, University of, Santa Cruz	4	Lincoln University	1
California Institute of the Arts	1	Louisiana State University, Baton Rouge	1
California Institute of Technology	10	Lowell, University of	7
California, Polytechnic State University	1	Loyola University of Los Angeles	1
California State College	1	Lynchburg College	1
California State University, Fullerton	1	Macalester College	1
California State University, Humboldt	1	Maine, University of, Orono	4
California State University, Long Beach	1	Manhattan College	2
Carnegie-Mellon University	9	Maryland, University of, College Park	5
Case Western Reserve University	3	Marquette University	2
Catholic University of America	4	Massachusetts College of Art	2
Chicago, University of	8	Massachusetts, University of, Amherst	8
Cincinnati, University of	5	Massachusetts Institute of Technology	192
City College, The	2	Miami, University of (Florida)	1
Claremont Men's College	1	Miami University (Ohio)	2
Clark University	1	Michigan, University of, Ann Arbor	7
Clarkson College of Technology	1	Michigan, University of, Dearborn	1
Colby College	2	Michigan State University	2
Colgate University	1	Michigan Technological University	1
Colorado, University of	7	Middlebury College	1
Colorado College, The	1	Minneapolis College of Art and Design	1
Colorado School of Mines	1	Minnesota, University of	4
Columbia University	13	Mississippi, University of	1
Concordia College	1	Mississippi State University	2
Connecticut, University of	6	Missouri, University of, Kansas City	1
Cooper Union, The	5	Missouri, University of, Rolla	2
Cornell University	21	Montana State University	1
C. W. Post Center	1	Morehouse College	1
Dartmouth College	5	Mount Holyoke College	2
Davidson College	1	Naval Postgraduate School	1
Dayton, University of	1	Nebraska, University of	1
Delaware, University of	2	New Hampshire, University of	3
Denver, University of	1	New Haven, University of	2
DePaul University	1	New Mexico, University of	3
Dowling College	1	New Orleans, University of	2
Drexel University	1	New York University	4
Duke University	4	New York, City University of	6
Eastern Illinois University	1	New York Institute of Technology	1
Emmanuel College	2	New York, State University of, Albany	2
Evansville, University of	1	New York, State University of, Buffalo	3
Evergreen State College, The	1	New York, State University of, Maritime College	4
Florida, University of	4	New York, State University of, Stonybrook	6
Florida Agricultural and Mechanical University	1	Nichols College	1
Florida Atlantic University	1	North Carolina, University of, Ashville	1
Florida Institute of Technology	1		
Florida State University	1		
Franklin and Marshall College	1		

North Carolina State University, Raleigh	3	Wisconsin, University of, Milwaukee	2
Northeastern University	10	Worcester Polytechnic Institute	7
Northern Illinois University	2	Yale	16
Northwestern University	2	U. S. Territories and Dependencies	
Notre Dame of Maryland, College of	1	Puerto Rico, University of, Mayaguez	3
Oakland University	1	Universidad Mundual Barbosa, Hato Rey	
Oberlin College	3	Puerto Rico	1
Ohio State University	12	Total United States	959
Oklahoma State University	1		
Oregon, University of	3		
Oregon State University	1		
Pace College	1	Ain Shans University (Egypt)	1
Pacific, University of	1	Alberta, University of (Canada)	2
Parks College of Aeronautical Technology	1	Al-Jami'ah Al-Amiriyah Fi Bayrut (Lebanon)	2
Pennsylvania, University of	13	Al-Jami'ah Al-Lubnaniyah (Lebanon)	1
Pennsylvania State University, The	9	American University (Egypt)	1
Pittsburgh, University of	2	Architecture, School of (India)	2
Polytechnic Institute of New York	5	Arhus Universitet (Denmark)	1
Princeton University	21	Asian Institute of Technology (Thailand)	1
Purdue University	8	Attmadu Bello University (Nigeria)	1
Queens College	1	Australian National University (Australia)	1
Quincy College	1	Banaras Hindu University (India)	1
Reed College	5	Belgrade, University of (Yugoslavia)	1
Rensselaer Polytechnic Institute	7	Birla Institute of Science and Technology (India)	1
Rhode Island, University of	4	Birmingham, University of (England)	1
Rhode Island College	1	Bogazici Universitesi (Turkey)	1
Rhode Island School of Design	1	Bombay, University of (India)	1
Rice University	3	British Columbia, University of (Canada)	1
Rochester, University of	4	Cairo University (Egypt)	3
Rush University	1	Cambridge, University of (England)	3
Rutgers, The State University	9	Changchun Institute of Geological Surveying (Peoples Republic of China)	1
Santa Clara, University of	2	Chulalongkorn University (Thailand)	2
Simmons College	1	Chung-Yuan College of Science and Engineering (Republic of China)	1
Smith College	3	City University, The (England)	1
South Florida, University of	1	Ecole Centrale des Arts et Manufactures (France)	5
Southeastern University	1	Ecole des Beaux Arts (France)	1
Southern California, University of	2	Ecole des Mines (France)	1
Southwest Missouri State University	1	Ecole Nationale des Ponts et Chaussees (France)	5
Stanford University	14	Ecole Nationale des travaux Publics de l'Etat (France)	1
Stevens Institute of Technology	1	Vauex en Velin (France)	1
Swarthmore College	4	Ecole Nationale Superieure de Chime de Paris (France)	2
Syracuse University	1	Ecole Nationale Superieure d'Ingenieurs de Mecanique de Poitiers (France)	1
Temple University	1	Ecole Nationale Superieure de l'Aeronautique et de l'Espace (France)	2
Texas, University of, Austin	5	Ecole Nationale Superieure des Industries (France)	1
Texas A & M University	4	Ecole Nationale Superieure des Telecommunications (France)	1
Trinity College (Connecticut)	4	Ecole Polytechnique (France)	3
Tufts University	11	Ecole Superieure d'Electricite (France)	1
Tulane University	4	Ege Universitesi (Turkey)	1
Union College (New York)	3	Eidgenossische Technische Hochschule (Switzerland)	2
United States Air Force Academy	8	Escuela Tecnica Superior de Ingenieros Aeronauticos (Spain)	1
United States Coast Guard Academy	5	Escuela Tecnica Superior de Ingenieros Industriales (Spain)	1
United States Merchant Marine Academy	1	Essex, University of (England)	2
United States Military Academy	4	Ethnikon Metsovian Polytechneion Athenai (Greece)	6
United States Naval Academy	6	Faculte Universitaire Catholique de Mons (Belgium)	1
Utah, University of	2	Glasgow, University of (Scotland)	1
Valparaiso University	1	Ha'Technion-Machon Technologi le Israel (Israel)	2
Vanderbilt University	2	Ha'Universita Ha'Ivrit Birushalayim (Israel)	2
Vassar College	1	Handelshogskolan i Stockholm (Sweden)	1
Vermont, University of	1	Han Yang Hag Gyo (Korea)	1
Villanova University	1	Hitotsubashi Daigaku (Japan)	1
Virginia, University of	6		
Virginia Polytechnic Institute and State University	3		
Virginia State College	1		
Washington, University of	6		
Washington University	3		
Washington State University	1		
Wayne State University	1		
Webb Institute of Naval Architecture	1		
Wellesley College	2		
Wentworth Institute of Technology	1		
Wesleyan University (Connecticut)	3		
West Georgia College	1		
West Virginia University	1		
Western Illinois University	1		
Williams College	7		
Wisconsin, University of, Madison	13		

Ibadan, University of (Nigeria)	1	Toronto, University of (Canada)	5
Imperial College of Science and Technology (England)	4	Universidad Anahuac Mexico (Mexico)	2
Indian Institute of Management (India)	1	Universidad Autonoma Metropolitana (Mexico)	1
Indian Institute of Technology, Bombay (India)	1	Universidad Catolica de Santiago de Guayaquil (Ecuador)	1
Indian Institute of Technology, Kanpur (India)	5	Universidad Centroamericana "Jose Simeon Canas" (El Salvadore)	1
Indian Institute of Technology, Kharagpur (India)	1	Universidad Complutense de Madrid (Spain)	1
Indian Institute of Technology, Madras (India)	1	Universidad de Barcelona (Spain)	1
Indian Institute of Technology, New Delhi (India)	1	Universidad de Chile (Chile)	1
Institut National Politechnique de Grenoble (France)	1	Universidad de Los Andes (Colombia)	2
Instituto Militar de Engenharia (Brazil)	1	Universidad Iberoamericana (Mexico)	1
Instituto Tecnologico Autonomo de Mexico (Mexico)	1	Universidad Nacional Autonoma de Mexico (Mexico)	5
Instituto Tecnologico de Monterrey (Mexico)	1	Universidad Nacional de Colombia (Colombia)	1
Istanbul Teknik Universitesi (Turkey)	3	Universidad Nacional de Cordoba (Argentina)	1
Jilin University of Technology (Peoples Republic of China)	1	Universidad Simon Bolivar (Venezuela)	2
Kasetsart University (Thailand)	1	Universidade Federal de Minas Gerais (Brazil)	1
Katholieke Universiteit te Leuven (Belgium)	3	Universidade Federal do Rio de Janeiro (Brazil)	1
Keio Gijuku Daigaku (Japan)	2	Universita degli Studi di Bologna (Italy)	1
Kobe Daigaku (Japan)	1	Universita degli Studi di Genova (Italy)	1
Korean Advanced Institute of Science (Korea)	1	Universita degli Studi di Roma (Italy)	2
Kyoto Daigaku (Japan)	6	Universita degli Studi di Pisa (Italy)	1
Kyushu Daigaku (Japan)	2	Universitat Tel-Aviv (Israel)	1
Latvin State University, Riga (U.S.S.R.)	1	Universite de Paris-Sorbonne (France)	1
London, University of (England)	7	Universite Paris, VI (France)	1
London School of Economics and Political Science (England)	2	Universite libre de Bruxelles (Belgium)	1
Manchester Institute of Science and Technology (England)	2	University College, Dublin (Ireland)	1
Manitoba, University of (Canada)	1	University College, London (England)	1
McGill University (Canada)	5	University College, The (Tanzania)	1
Melbourne, University of (Australia)	1	Univerzitet u Beogradu (Yugoslavia)	1
Montreal, University of (Canada)	1	Victoria University, Wellington (New Zealand)	2
Moscow State University (U.S.S.R.)	1	Wagenbauschule Hamburg (West Germany)	1
National Cheng Kung University (Republic of China)	1	Waseda Daigaku (Japan)	1
National Chengchi University (Republic of China)	1	Waterloo, University of (Canada)	4
National Taiwan University (Republic of China)	8	Western Australia Institute of Technology (Australia)	1
National Tsing Hua University (Republic of China)	1	Western Ontario, University of (Canada)	1
Newcastle upon Tyne, University of (England)	1	Witwatersrand, University of The (South Africa)	2
Nihon Daigaku (Japan)	1	Yokohama Kokuritsu Daigaku (Japan)	1
Orta Dogu Teknik Univeritesi (Turkey)	1		
Oxford, University of (England)	3	Total Foreign	244
Pamantasan ng Philipinas (Philippines)	2		
Politecnico di Milano (Italy)	1	Grand Total	1,203
Politecnico di Torino (Italy)	1		
Poona University (India)	1		
Pretoria, University of (South Africa)	1		
Queen's University, Kingston (Canada)	4		
Reading, University of (England)	1		
Royal Melbourne Institute of Technology (Australia)	1		
Ruprecht-Karl-Universitat (West Germany)	1		
Seoul Dae Hag Gyo (Korea)	7		
Singapore, University of (Singapore)	2		
Southampton, University of (England)	1		
Stockholms Universitet (Sweden)	1		
Technische Hochschule Darmstadt (West Germany)	1		
Technische Universitat, Berlin (West Germany)	1		
Technische Universitat, Hannover (West Germany)	1		
Tekniska Hogskolan I Lund (Sweden)	1		
Tokyo Daigaku (Japan)	10		

¹Graduates of 232 Colleges and Universities, including U. S. Territories and Dependencies in the United States and 139 Foreign Colleges and Universities.

Table VII Geographic Distribution of Students, 1979-80

Under-grad.		Grad.	Under-grad.		Grad.	Under-grad.		Grad.
United States			U. S. Territories and Dependencies			Italy	2	27
Alabama	19	6	Puerto Rico	19	12	Ivory Coast	-	5
Alaska	10	1	Virgin Islands	2	1	Jamaica	2	-
Arizona	30	6	U.S.Citizens			Japan	15	84
Arkansas	10	6	Foreign Address	51	66	Jordan	-	3
California	217	199	Total U.S.	4,118	3,208	Kenya	-	1
Colorado	37	28	Foreign Countries*			Korea	35	43
Connecticut	166	72	Afghanistan	-	2	Kuwait	-	1
Delaware	13	14	Algeria	2	12	Lebanon	4	23
District of Columbia	22	18	Argentina	1	12	Malaysia	14	19
Florida	120	37	Australia	-	12	Mauritania	-	2
Georgia	34	23	Austria	-	3	Mexico	1	39
Hawaii	17	11	Bahrain	-	1	Monaco	1	-
Idaho	5	4	Bangladesh	3	5	Morocco	-	1
Illinois	154	73	Belgium	-	15	Nepal	1	2
Indiana	26	12	Bermuda	1	-	Netherlands	6	2
Iowa	18	12	Bolivia	2	-	Netherlands-Antilles	1	-
Kansas	19	8	Brazil	1	44	New Zealand	-	2
Kentucky	12	9	Brunei	1	-	Nigeria	1	24
Louisiana	15	9	Burundi	-	1	Norway	1	7
Maine	39	13	Canada	52	106	Pakistan	15	12
Maryland	139	66	Cape Verde Islands	-	1	Panama	1	-
Massachusetts	653	1,398	Chile	1	16	Paraguay	-	2
Michigan	101	71	China, Peoples Republic of	1	1	Peru	4	5
Minnesota	47	15	China, Republic of	27	121	Philippines	3	6
Mississippi	14	8	Columbia	5	11	Poland	2	5
Missouri	48	22	Costa Rica	1	-	Portugal	1	6
Montana	6	3	Cuba	2	-	Rumania	-	1
Nebraska	16	5	Cypruss	-	3	Saudi Arabia	-	6
Nevada	5	5	Czechoslovakia	1	1	Singapore	7	12
New Hampshire	29	23	Denmark	-	3	South Africa	2	11
New Jersey	295	126	Dominican Republic	-	1	Spain	1	28
New Mexico	8	5	Ecuador	1	5	Sri Lanka	4	3
New York	782	313	Egypt	1	22	Sudan	-	2
North Carolina	52	29	El Salvador	-	2	Sweden	2	8
North Dakota	5	-	Ethiopia	-	2	Switzerland	-	7
Ohio	129	90	Finland	-	1	Syria	-	1
Oklahoma	14	7	France	4	51	Tanzania	-	2
Oregon	38	14	Germany	8	21	Thailand	4	9
Pennsylvania	213	115	Ghana	12	5	Trinidad	6	1
Rhode Island	31	18	Greece	15	62	Tunisia	-	1
South Carolina	13	8	Guatemala	-	2	Turkey	8	22
South Dakota	5	4	Guyana	2	-	Uganda	1	1
Tennessee	21	16	Honduras	-	1	United Kingdom	23	50
Texas	130	52	Hong Kong	23	49	Uruguay	2	5
Utah	6	9	Iceland	-	1	U.S.S.R.	2	1
Vermont	23	14	India	17	85	Venezuela	5	28
Virginia	108	56	Indonesia	3	5	Vietnam	8	5
Washington	57	40	Iran	15	64	Yugoslavia	3	7
West Virginia	5	8	Iraq	1	4	Zaire, Republic of	-	1
Wisconsin	66	28	Ireland	-	2	Zambia	1	-
Wyoming	4	-	Israel	2	29	Stateless	6	11
						Total Foreign	399	1,328
						Grand Total	4,517	4,536

*Country of Citizenship

Table VIII Number of Degrees Awarded in September 1979, February 1980, and June 1980

	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	-	-	-	-	11	6	15	4	3	15	-	-	-	-	15	9	30
Architecture Studies	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
Art and Design	-	7	23	-	-	-	-	-	-	-	-	-	-	-	-	7	23
Visual Studies	-	-	-	4	3	3	-	-	-	-	-	-	-	-	4	3	3
Urban Studies and Planning	-	1	9	-	5	5	24	-	-	-	3	6	2	-	8	12	35
Total	-	8	32	4	3	4	16	11	39	4	3	15	-	-	27	31	92
School of Engineering																	
Aeronautics and Astronautics	2	7	24	-	-	-	-	-	-	-	2	2	6	-	17	20	48
Ceramics	-	8	84	1	-	-	-	-	-	-	-	-	3	-	1	-	-
Chemical Engineering	6	8	13	10	16	-	-	-	-	5	3	3	3	3	25	26	109
Undesignated	2	2	13	-	-	-	-	-	-	-	-	-	-	-	2	2	13
Chemical Engineering Practice	-	-	-	2	12	10	-	-	-	-	-	-	-	-	2	12	10
Civil Engineering	1	14	45	24	26	44	-	-	-	1	1	1	2	3	29	46	99
Undesignated	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Computer Science and Engineering	8	19	72	-	-	-	-	-	-	-	-	-	-	-	8	19	72
Electrical Engineering	20	26	124	-	-	-	-	-	-	6	7	17	17	12	20	26	124
Electrical Engineering and Computer Science	-	-	-	25	43	80	-	-	-	-	-	-	3	4	51	66	109
Undesignated	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Environmental Engineer	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	1
Materials Engineering	-	-	-	2	1	1	-	-	-	-	-	-	-	-	2	1	1
Materials Science	-	-	-	1	4	5	-	-	-	-	-	-	-	-	1	4	5
Materials Science and Engineering	2	3	32	-	-	-	-	-	-	-	-	4	4	3	9	12	40
Undesignated	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Mechanical Engineering	4	13	84	18	41	36	-	-	-	4	-	3	1	5	27	65	132
Undesignated	-	1	20	-	-	-	-	-	-	-	-	-	6	2	-	1	20
Metallurgy	-	-	-	2	2	6	-	-	-	-	-	-	-	-	2	2	6
Naval Architecture and Marine Engineering	1	1	3	5	4	10	-	-	-	-	-	-	-	-	6	5	13
Nuclear Engineering	2	10	6	15	16	-	-	-	-	1	3	4	3	7	12	26	38
Ocean Engineering	1	2	7	2	4	6	-	-	-	2	15	1	1	2	6	7	30
Ocean Systems Management	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1
Polymers	-	-	-	-	3	4	-	-	-	-	-	-	-	-	-	3	4
Shipping and Shipbuilding Management	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	2	-
Technology and Policy	-	-	-	1	4	10	-	-	-	-	-	-	-	-	1	4	10
Textile Technology	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Transportation	-	-	-	-	1	2	-	-	-	-	-	-	-	-	-	1	2
Total	49	96	521	114	180	265	-	-	-	15	17	43	33	37	221	351	890

School of Humanities and Social Science																					
Economics	1	6	14	1	-	1	-	-	-	-	9	5	13	-	-	-	11	11	28		
Humanities and Engineering	1	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	2		
Humanities and Science	3	5	14	-	-	-	-	-	-	-	-	-	-	-	-	-	3	5	14		
Linguistics	-	-	-	-	-	-	-	-	-	-	2	2	5	-	-	-	2	2	5		
Philosophy	-	-	6	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	6		
Political Science	1	1	7	2	5	4	-	-	-	-	3	2	6	-	-	-	6	8	17		
Psychology	-	-	-	-	-	-	-	-	-	-	1	-	2	-	-	-	1	-	2		
Total	6	13	43	3	5	5	-	-	-	-	15	10	26	-	-	-	24	28	74		
Alfred P. Sloan School of Management																					
Management	2	7	37	7	11	172	-	-	-	-	5	2	1	-	-	-	14	20	210		
School of Science																					
Biochemical Engineering	-	-	-	-	3	1	-	-	-	-	-	-	-	-	-	-	-	3	1		
Biology	-	-	-	-	-	2	-	-	-	-	4	8	3	-	-	-	4	8	5		
Undesignated	3	9	24	-	-	-	-	-	-	-	-	-	-	-	-	-	3	9	24		
Chemistry	4	4	30	1	1	2	-	-	-	-	15	11	13	-	-	-	20	16	45		
Earth and Planetary Sciences	1	-	19	7	4	1	-	-	-	-	4	4	4	-	-	-	12	8	24		
Food Science and Technology	-	-	-	1	3	1	-	-	-	-	-	-	-	-	-	-	1	3	1		
Interdisciplinary Science	-	-	-	2	1	1	-	-	-	-	-	-	-	-	-	-	2	1	1		
Undesignated	-	2	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	4		
Life Sciences	2	21	63	-	-	-	-	-	-	-	-	-	-	-	-	-	2	21	63		
Mathematics	2	6	37	1	2	2	-	-	-	-	6	4	14	-	-	-	9	12	53		
Meteorology	-	-	-	5	1	2	-	-	-	-	-	3	-	-	-	-	5	4	2		
Neural and Endocrine Regulation	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	2		
Nutrition and Food Science	-	-	-	-	-	2	-	-	-	-	6	8	8	-	-	-	6	9	8		
Nutritional Biochemistry and Metabolism	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-	-	8	2	4		
Oceanography	-	-	-	8	2	4	-	-	-	-	-	-	-	-	-	-	8	2	4		
Physics	9	7	56	3	3	6	-	-	-	-	6	8	8	-	-	-	19	18	71		
Total	21	49	233	28	21	24	-	-	-	-	41	46	50	1	1	1	91	117	308		
Operations Research	-	-	-	1	4	1	-	-	-	-	-	-	-	-	-	-	1	4	1		
Without Course Specification	-	-	-	17	16	12	-	-	-	-	-	-	-	-	-	-	17	16	12		
Awarded Jointly with Woods Hole Oceanographic Institution																					
Biology	-	-	-	-	-	-	-	-	-	-	-	3	1	-	-	-	-	3	1		
Earth and Planetary Sciences	-	-	-	-	-	-	-	-	-	-	-	6	3	-	-	-	-	6	3		
Meteorology	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-		
Ocean Engineering	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-		
Total	-	-	-	-	-	-	-	-	-	-	-	10	4	-	-	-	1	11	5		
Grand Total	78	173	866	174	240	483	16	11	39	4	3	15	16	18	43	11	22	19	396	578	1,592

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										Calendar year since 1976 (included in decade total)							
	1868-70	1871-80	1881-90	1891-1900	1901-10	1911-20	1921-30	1931-40	1941-50	1951-60	1961-70	1971-	Grand Total	1976	1977	1978	1979	1980*
School of Architecture and Planning¹																		
Architecture	-	12	24	162	188	233	223	23	-	-	-	-	865	-	-	-	-	-
Undesignated	-	-	-	-	-	-	-	23	-	-	2	18	20	2	1	-	1	-
Architectural Engineering ²	-	-	-	-	-	-	108	64	-	-	-	-	172	-	-	-	-	-
Art and Design	-	-	-	-	-	-	-	-	-	26	433	459	459	46	49	42	36	30
Urban Studies	-	-	-	-	-	-	-	-	-	-	156	156	156	25	11	13	14	10
Undesignated	-	-	-	-	-	-	-	-	-	-	2	2	2	-	-	1	-	-
Total	-	12	24	162	188	233	331	87	-	-	28	609	1,674	73	61	56	51	40
School of Engineering																		
Aeronautics and Astronautics ¹¹	-	-	-	-	-	-	68	287	526	395	556	262	2,094	13	14	25	42	31
Undesignated	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-
Building Engineering and Construction	-	-	-	-	-	-	32	99	114	131	-	-	376	-	-	-	-	-
Chemical Engineering	-	-	-	91	123	372	571	434	740	726	421	494	3,972	39	52	83	95	92
Undesignated	-	-	-	-	-	-	-	-	-	3	89	89	92	7	11	9	13	15
Chemical Engineering Practice	-	-	-	-	-	-	99	90	95	108	1	-	393	-	-	-	-	-
Civil Engineering	12	84	86	256	407	504	653	284	272	457	252	496	3,763	59	54	65	62	59
Undesignated	-	-	-	-	-	-	-	-	-	7	26	26	33	-	2	1	3	1
Computer Science and Engineering	-	-	-	-	-	-	-	-	-	-	454	454	454	84	80	94	95	91
Electrical Engineering	-	-	72	335	349	468	1,000	719	1,218	1,518	1,941	1,835	9,455	137	138	138	189	150
Undesignated	-	-	-	-	-	-	-	-	-	-	2	2	2	-	-	-	-	1
Electrochemical Engineering ³	-	-	-	-	28	84	133	56	-	-	-	-	301	-	-	-	-	-
General Engineering	-	-	-	-	-	6	226	222	230	133	-	-	817	-	-	-	-	-
Materials Science and Engineering ⁴	-	-	-	-	-	-	-	52	194	311	186	161	904	19	12	10	22	35
Undesignated	-	-	-	-	-	-	-	-	-	-	1	26	27	-	1	3	4	1
Mechanical Engineering	5	40	147	329	502	623	797	602	1,164	1,049	563	663	6,484	69	73	84	129	97
Undesignated	-	-	-	-	-	-	-	-	-	-	12	140	152	10	13	12	16	21
Military Engineering	-	-	-	-	-	-	1	4	-	-	-	-	5	-	-	-	-	-
Mining Engineering and Metallurgy	8	44	64	74	250	129	174	137	-	-	-	-	880	-	-	-	-	-
Naval Architecture and Marine Engineering	-	-	-	43	133	69+	100	173	234	139	69	52	1,012	7	1	7	8	4
Nuclear Engineering	-	-	-	-	-	-	-	-	-	-	-	34	34	34	3	12	9	10
Ocean Engineering	-	-	-	-	-	-	-	-	-	-	-	57	57	9	10	2	6	9
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	4,793	31,573	453	465	545	696	617

School of Humanities and Social Science

Economics	-	-	-	-	-	-	-	-	-	129	259	388	22	34	25	23	20
Economics, Politics and Engineering or Science	-	-	-	-	-	61	152	100	-	313	-	313	-	-	-	-	-
Humanities and Engineering or Science ⁵	-	-	-	-	-	-	49	412	320	781	23	14	14	14	18	22	22
Philosophy	-	-	-	-	-	-	-	-	37	37	3	5	5	5	2	6	6
Political Science ⁹	-	-	-	-	-	-	-	-	114	129	243	7	13	8	9	8	8
Total	-	-	-	-	-	61	201	755	745	1,762	55	66	52	52	52	56	56

Alfred P. Sloan School of Management⁶

Business and Engineering Administration Management ¹⁰	-	-	-	-	142	872	641	909	732	-	-	3,296	-	-	-	-	-
Total	-	-	-	-	142	872	641	909	732	565	552	1,289	52	51	40	35	44

School of Science

Biology ⁷	-	3	11	25	27	49	57	129	74	116	16	-	-	-	-	-	-
Undesignated	-	-	-	-	-	-	-	-	-	-	-	507	-	-	-	-	-
Chemistry	2	27	80	154	151	111	141	166	232	207	307	343	36	26	24	35	33
Earth and Planetary Sciences ⁸	-	-	-	8	6	3	36	22	32	141	109	484	61	40	57	62	34
Undesignated	-	-	-	-	-	-	-	-	-	-	7	223	580	28	19	30	23
Food Technology and Biochemical Engineering	-	-	-	-	-	-	-	-	35	62	11	20	-	-	-	-	-
General Science or General Course	2	11	17	49	20	26	17	73	58	62	-	-	-	-	-	-	-
Interdisciplinary Science-Undesignated	-	-	-	-	-	-	-	-	-	-	-	81	9	5	9	6	6
Life Sciences ⁷	-	-	-	-	-	-	-	-	-	-	291	883	1,174	110	97	106	72
Mathematics	-	-	-	-	-	-	19	48	72	220	831	865	2,055	86	90	74	59
Meteorology	-	-	-	-	-	-	-	-	56	38	-	94	-	-	-	-	-
Physics	-	5	6	24	19	21	49	170	306	617	1,079	928	3,224	106	84	92	91
Total	4	46	114	260	223	210	319	608	865	1,463	2,651	3,827	10,590	436	361	388	351

Grand Total	29	226	507	1,579	2,257	2,963	5,410	4,515	6,626	7,535	8,011	10,526	50,184	1,069	1,004	1,081	1,182
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* Includes only February and June Degrees

¹ Two received the degree in Naval Architecture, Course XIII-B, in 1916 and three in 1917

² See also Table XI

³ Prior to 1923 degrees were awarded in Architecture

⁴ Prior to 1909 this course was designated as Option 3 (Electrochemistry) or Physics

⁵ Prior 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

⁶ Prior to 1958 these degrees were included in General Engineering and General Science or General Course

⁷ Changed to Alfred P. Sloan School of Management 1963

⁸ Changed to Life Sciences beginning January 1962

⁹ Changed from Geology and Geophysics to Earth Sciences in February 1961, changed from Earth Sciences to Earth and Planetary Sciences in February 1970

¹⁰ Prior to September 1965, these degrees were included in Economics, Politics and Engineering or Science

¹¹ Prior to 1959, Business and Engineering Administration, changed from Industrial Management to Management in February 1967

¹² Prior to 1960 Aeronautical Engineering

Table X Number of Degrees of Master of Science Awarded

	Total by decade										Calendar year since 1976 (Included in decade total)					
	1886-90	1891-1900	1901-10	1911-20	1921-30	1931-40	1941-50	1951-60	1961-70	1971-	Grand Total	1976	1977	1978	1979	1980*
School of Architecture and Planning¹																
Architecture	-	8	45	31	-	-	-	-	-	-	-	-	-	-	-	-
Architecture Studies	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	1
Architectural Engineering ²	-	-	-	-	9	10	-	-	-	-	-	-	-	-	-	-
Visual Studies	-	-	-	-	-	-	-	-	-	-	18	-	-	-	-	6
Total	-	8	45	31	9	10	-	-	-	19	122	-	-	-	12	7
School of Engineering																
Aeronautics and Astronautics ¹¹	-	-	-	17	59	76	307	375	645	398	1,877	37	36	42	36	25
Building Engineering and Construction	-	-	-	-	-	-	21	66	21	-	108	-	-	-	-	-
Ceramics	-	-	-	-	-	3	3	13	20	30	69	4	3	7	3	-
Chemical Engineering	3	2	18	18	69	152	275	467	398	273	1,657	24	34	36	43	26
Chemical Engineering Practice	-	-	-	-	245	284	241	256	102	285	1,413	33	31	31	28	22
Civil Engineering	-	1	4	27	53	179	194	350	548	723	2,079	104	75	73	91	70
Electrical Engineering and Computer Science (including VI-A) ¹²	-	-	7	43	462	474	546	1,164	1,529	1,175	5,400	126	144	116	119	123
Electrochemical Engineering	-	-	4	4	16	8	-	-	-	-	28	-	-	-	-	-
Fuel and Gas Engineering	-	-	-	-	15	11	-	-	-	-	26	-	-	-	-	-
Materials Engineering	-	-	-	-	-	-	-	-	-	37	37	4	2	8	8	2
Materials Science	-	-	-	-	-	-	-	-	-	40	40	4	10	4	6	9
Mechanical Engineering	-	1	8	22	100	175	357	525	690	713	2,591	67	71	83	71	77
Metallurgy	-	-	-	-	8	36	92	230	205	101	672	3	7	12	6	8
Mining Engineering	-	-	-	9	8	16	-	-	-	-	33	-	-	-	-	-
Naval Architecture and Marine Engineering	-	-	2	1	5	20	60	165	281	227	761	26	29	24	24	14
Naval Construction and Engineering	-	-	39	48	101	89	206	67	282	340	483	-	-	-	-	-
Nuclear Engineering ³	-	-	-	-	-	-	-	67	3	152	155	19	15	17	17	10
Ocean Engineering	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	1
Ocean Systems Management	-	-	-	-	-	5	-	-	-	16	5	-	-	-	-	-
Petroleum Engineering	-	-	-	-	-	-	-	-	-	16	16	4	-	2	2	7
Polymerics	-	-	-	-	-	-	-	-	-	-	14	-	-	-	-	-
Railroad Engineering	-	-	-	-	-	14	-	-	-	-	191	-	-	-	-	-
Sanitary Engineering	-	-	2	8	3	10	53	99	16	-	191	-	-	-	-	-
Shipping and Shipbuilding Management	-	-	-	-	-	-	-	4	15	56	75	18	3	7	8	2
Technology and Policy	-	-	-	-	-	-	-	-	-	38	38	-	1	9	14	14
Textile Technology	-	-	-	-	-	1	31	34	20	11	97	-	-	-	-	1
Transportation	-	-	-	-	-	-	-	-	-	3	3	-	-	-	-	3
Total	-	5	64	197	1,144	1,553	2,386	3,815	4,775	4,619	18,558	502	508	513	499	445

School of Humanities and Social Science

Economics ⁷	-	-	-	-	-	19	22	41	2	3	3	2	1
Economics and Engineering or Science ¹⁰	-	-	-	12	16	19	10	57	-	-	-	-	-
Linguistics	-	-	-	-	-	-	7	8	-	-	-	-	-
Philosophy	-	-	-	-	-	-	2	10	1	-	1	-	-
Political Science ⁷	-	-	-	-	-	-	25	129	11	18	11	16	9
Psychology ⁴	-	-	-	-	-	-	7	16	1	2	1	-	-
Total	-	-	-	-	12	16	64	150	15	23	16	18	10

Alfred P. Sloan School of Management⁵

Management ⁸	-	-	-	4	60	581	1,274	1,847	161	217	201	203	183
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School of Science

Biochemical Engineering	-	-	-	-	-	-	17	29	4	4	6	1	4
Biochemistry	-	-	-	-	-	3	6	14	3	-	1	-	-
Biology	-	1	1	10	25	29	12	43	2	6	3	-	2
Biophysics	-	-	-	-	-	2	3	8	-	1	1	-	-
Chemistry	2	3	7	22	53	46	97	69	9	7	5	5	3
Earth and Planetary Sciences	-	-	-	-	-	-	7	88	10	13	5	11	5
Food Science and Technology	-	-	-	-	12	44	57	53	3	8	7	10	4
Food Technology	-	-	-	-	-	-	3	-	-	-	-	-	-
General Science	-	1	-	-	17	48	71	-	-	-	-	-	-
Geology and Geophysics ⁹	-	-	2	5	21	15	-	-	7	8	4	9	2
Interdisciplinary Science	-	-	-	-	45	96	73	63	9	10	4	9	4
Mathematics	-	-	-	2	9	25	87	82	6	13	7	11	3
Meteorology ⁶	-	-	-	-	35	118	-	6	-	1	3	-	2
Neural and Endocrine Regulation	-	-	-	-	-	-	23	23	-	-	-	-	-
Nutrition	-	-	-	-	-	7	25	93	16	13	14	10	6
Nutritional Biochemistry and Metabolism	-	-	-	-	-	-	28	21	-	-	-	3	1
Oceanography	-	-	-	-	50	121	138	137	9	13	14	15	9
Physics	-	3	2	2	16	40	-	13	-	5	4	4	-
Toxicology	-	-	-	-	-	-	-	13	-	-	-	-	-
Total	2	8	12	41	185	514	647	735	78	102	78	88	45

Operations Research Without Course Specification	-	-	-	5	308	357	299	374	9	5	7	4	5
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Grand Total	2	21	121	274	1,544	2,083	7,061	7,817	793	883	867	865	723
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*Includes only February and June degrees
¹See Table XI
²Prior to 1923 degrees were awarded in Architecture
³Prior to 1959 included in Chemical Engineering
⁴Prior to September 1964 included in Economics, Politics and Engineering or Science
⁵Considered Engineering until 1950
⁶Considered Engineering until 1956
⁷Prior to September 1965 included in Economics, Politics and Engineering or Science
⁸Prior to February 1967 Industrial Management
⁹Changed to Earth and Planetary Sciences beginning February 1970
¹⁰Includes six degrees in Political Science awarded 1965
¹¹Prior to 1960 Aeronautical Engineering
¹²Changed 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 Awarded

	Total by decade										Grand Total	Calendar year since 1976 (included in decade total)				
	1921-30	1931-40	1941-50	1951-60	1961-70	1971-	1976	1977	1978	1979		1980*				
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 in City Planning	-	18	82	114	152	311	32	30	29	49	677	32	30	29	49	
Master of Architecture	-	-	-	-	23	273	38	36	30	37	296	38	36	30	37	
Master of Architecture in Advanced Studies	-	-	-	-	-	186	19	24	22	24	186	19	24	22	24	
Grand Total	63	259	299	566	577	796	89	90	81	110	2,560	89	90	81	110	

*Includes only February and June degrees

¹From 1935 to 1944, Bachelor of Architecture in City Planning²Degree of Bachelor in Architecture changed to degree of Master of Architecture 1972³Degree 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 1976 (included in decade total)						
	1949-60	1961-1970	1971-	1976	1977		1978	1979	1980*				
Building Engineer ³	5	2	-	7	-	7	-	-	-	-	-	-	-
Chemical Engineer	17	31	65	113	8	113	4	3	8	-	-	-	-
Civil Engineer	21	78	64	163	6	163	1	4	2	-	-	-	-
Electrical Engineer	132	444	380	956	41	956	39	24	24	-	-	-	-
Engineer in Aeronautics and Astronautics ¹	35	58	24	117	3	117	2	2	1	-	-	-	-
Environmental Engineer	-	-	12	12	2	12	1	-	-	-	-	-	-
Marine Mechanical Engineer	7	2	1	10	-	10	-	-	-	-	-	-	-
Materials Engineer	-	7	8	15	1	15	4	-	-	-	-	-	-
Mechanical Engineer	102	166	100	368	6	368	6	7	3	-	-	-	-
Metallurgical Engineer	24	18	7	49	-	49	1	-	-	-	-	-	-
Meteorologist ²	2	-	-	2	-	2	-	-	-	-	-	-	-
Naval Architect	11	21	17	49	3	49	-	-	-	-	-	-	-
Naval Engineer	334	246	20	600	-	600	-	-	-	-	-	-	-
Nuclear Engineer	-	37	72	109	6	109	17	12	7	-	-	-	-
Ocean Engineer	-	4	196	200	24	200	28	18	15	-	-	-	-
Sanitary Engineer ³	9	3	-	12	-	12	-	-	-	-	-	-	-
Total	699	1,117	966	2,782	100	2,782	99	95	65	60			
Awarded jointly with Woods Hole Oceanographic Institution													
Electrical Engineer	-	-	1	1	-	1	-	-	1	-	-	1	-
Ocean Engineer	-	-	15	15	-	15	-	1	3	1	-	-	-
Grand Total	699	1,117	967	2,783	100	2,783	99	96	66	61			

* Includes only February and June degrees

¹Prior to 1960 Aeronautical Engineer

²Degree discontinued after 1955

³Degree discontinued after 1964

Table XIII Number of Degrees of Doctor of Philosophy Awarded

	Total by decade										Calendar year since 1976 (included in decade total)			
	1907-10	1911-20	1921-30	1931-40	1941-50	1951-60	1961-70	1971-	Grand Total	1976	1977	1978	1979	1980*
School of Architecture and Planning														
Architecture	-	-	-	-	-	-	-	3	3	-	-	1	1	-
Urban Studies and Planning ⁶	-	-	-	-	-	-	24	70	94	6	9	7	12	8
Total	-	-	-	-	-	-	24	73	97	6	9	8	13	8
School of Engineering														
Aeronautics and Astronautics ⁷	-	-	-	-	-	6	57	97	160	11	6	8	9	8
Chemical Engineering	-	-	-	-	-	-	31	49	80	2	8	3	7	6
Civil Engineering	-	-	-	-	-	1	72	137	210	12	10	21	13	9
Electrical Engineering and Computer Science ⁹	-	-	-	-	1	9	248	359	617	27	27	44	42	24
Materials Science and Engineering ³	-	-	-	-	-	6	103	124	233	7	17	15	6	8
Mechanical Engineering	-	-	-	-	-	4	95	140	239	16	10	13	16	12
Nuclear Engineering	-	-	-	-	-	5	90	107	202	17	20	8	11	11
Ocean Engineering ⁸	-	-	-	-	-	-	15	42	57	5	6	9	6	3
Sanitary Engineering	-	-	-	-	-	2	3	-	5	-	-	-	-	-
Total	-	-	-	-	1	33	714	1,055	1,803	97	104	121	110	81
School of Humanities and Social Science														
Economics ¹	-	-	-	-	19	96	195	221	531	25	25	25	28	18
Group Psychology	-	-	-	-	8	1	-	-	9	-	-	-	3	7
Linguistics	-	-	-	-	-	-	35	65	100	9	2	6	3	1
Philosophy	-	-	-	-	-	-	8	23	31	2	3	2	1	1
Political Science	-	-	-	-	-	-	71	114	185	12	18	12	11	8
Psychology	-	-	-	-	-	3+	24	45	72	7	7	5	2	2
Total	-	-	-	-	27	100	333	468	928	55	55	50	45	36

Alfred P. Sloan School of Management
Management²

School of Science	1	10	17	21	38	105	164	207	8	11	20	18	3
Biology	-	1	10	17	21	38	105	356	15	19	19	17	11
Chemistry	7	19	59	146	180	342	427	1,578	43	33	25	37	24
Earth and Planetary Sciences ⁴	1	7	10	22	20	71	99	314	12	6	17	11	8
Mathematics	-	-	6	25	35	70	211	576	23	28	23	19	18
Meteorology	-	-	-	-	14	45	35	94	4	2	2	2	3
Nutrition and Food Science	-	-	-	4	28	66	149	247	17	17	18	23	16
Oceanography ⁵	-	-	-	-	-	11	-	11	-	-	-	-	-
Physics	-	2	6	48	159	283	390	1,260	47	36	33	39	16
Total	8	29	91	258	419	846	1,339	4,436	161	141	137	148	96

Awarded jointly with Woods Hole
Oceanographic Institution

Biology	-	-	-	-	-	-	14	14	3	1	3	1	4
Earth and Planetary Sciences	-	-	-	-	-	4	43	47	6	6	3	3	9
Electrical Engineering and Computer Science	-	-	-	-	-	-	1	1	-	1	-	-	-
Meteorology	-	-	-	-	-	1	15	16	1	2	1	1	1
Ocean Engineering	-	-	-	-	-	-	6	6	1	2	2	-	-
Total	-	-	-	-	-	5	79	84	11	12	9	5	14
Grand Total	8	29	91	258	447	979	2,504	7,555	338	332	345	242	238

* Includes only February and June degrees
¹ Previously included in Industrial Economics
² Changed from Industrial Economics to Economics 1966
³ Changed from Industrial Management to Management 1967
⁴ Includes Ceramics; Metallurgy and Materials Science changed to Material 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 1969
⁸ Prior to 1960 Aeronautical Engineering
⁹ Changed from Naval Architecture and Marine Engineering to Ocean Engineering 1971
¹⁰ Changed from Electrical Engineering and Computer Science 1975

Table XIV Number of Degrees of Doctor of Science Awarded

School of Engineering	Total by decade										Grand Total	Calendar year since 1976 (included in decade total)				
	1911-20	1921-30	1931-40	1941-50	1951-60	1961-70	1971-	1976	1977	1978		1979	1980*			
Aeronautics and Astronautics ¹	2	4	5	18	31	76	49	185	7	5	3	5	4			
Chemical Engineering	-	23	78	114	117	151	75	558	9	6	4	7	3			
Civil Engineering	-	2	12	23	46	75	44	202	3	5	3	1	5			
Electrical Engineering and Computer Science ⁵	3	12	30	34	141	124	66	410	5	4	3	8	4			
Electrochemical Engineering	-	1	1	-	-	-	-	2	-	-	-	-	-			
Materials Science and Engineering ⁶	-	14	32	86	194	201	101	628	15	6	12	12	9			
Mechanical Engineering	-	4	13	35	125	145	83	405	11	5	9	7	8			
Mineral Engineering	1	-	4	-	-	-	-	5	-	-	-	-	-			
Nuclear Engineering	-	-	-	-	9	55	53	117	5	8	6	4	5			
Ocean Engineering ⁴	-	1	-	-	2	6	11	20	-	-	1	1	-			
Petroleum Engineering	-	-	1	-	-	-	-	1	-	-	-	-	-			
Sanitary Engineering	-	-	2	3	18	2	-	25	-	-	-	-	-			
Total	6	61	178	313	683	835	482	2,558	55	39	41	45	38			
School of Science																
Chemistry	-	2	5	4	3	1	2	17	1	-	-	-	-			
Earth and Planetary Sciences ²	1	2	4	5	2	3	7	24	1	-	2	-	-			
Mathematics	-	2	3	-	1	1	2	9	-	-	-	-	-			
Meteorology	-	-	6	25	17	6	9	63	1	3	1	1	-			
Nutrition and Food Science	-	-	-	3	10	17	21	51	1	3	2	1	1			
Oceanography ³	-	-	-	-	-	1	-	1	-	-	-	-	-			
Physics	-	5	18	14	7	7	17	68	2	3	3	2	1			
Total	1	11	36	51	40	36	58	233	6	9	8	4	2			
Awarded jointly with Woods Hole Oceanographic Institution																
Earth and Planetary Sciences	-	-	-	-	-	-	1	1	-	1	-	-	-			
Meteorology	-	-	-	-	-	-	7	7	-	1	-	1	1			
Total	-	-	-	-	-	-	8	8	-	2	-	1	1			
Grand Total	7	72	214	364	723	871	548	2,799	61	50	49	50	41			

* Includes only February and June degrees

¹ Prior to 1960 Aeronautical Engineering² Changed from Geology and Geophysics to Earth and Planetary Sciences 1970³ Began in 1967-68 included in Earth and Planetary Sciences or Meteorology⁴ Began from Naval Architecture and Marine Engineering to Ocean Engineering 1970⁵ Changed from Electrical Engineering to Computer Science 1975⁶ Changed from Metallurgy and Materials Science to Materials Science and Engineering 1975

Table XV Summary of Degrees Awarded

(1868-1980)

Bachelor in Architecture (discontinued 1972)	722
Bachelor in City Planning (discontinued 1954)	31
Bachelor of Science	50,184
Master in Architecture (discontinued 1972)	648
Master in City Planning	667
Master in Public Health (discontinued 1944)	104
Master of Architecture	296
Master of Architecture in Advanced Studies	186
Master of Science	27,157
Advanced Engineering	2,782
Advanced Engineering awarded jointly with Woods Hole Oceanographic Institution	17
Doctor of Engineering (discontinued 1918)*	4
Doctor of Philosophy	7,471
Doctor of Philosophy awarded jointly with Woods Hole Oceanographic Institution	84
Doctor of Public Health (discontinued 1944)*	9
Doctor of Science	2,791
Doctor of Science awarded jointly with Woods Hole Oceanographic Institution	8
	<hr/>
	93,161

* See 1959 Report of the Registrar for details

WARREN D. WELLS

Office of the President and the Chancellor Vice President

The grouping of the departmental reports in this section reflects a decision by Dr. Paul E. Gray, the Chancellor and President-Elect, to realign senior administrative responsibilities in order to consolidate and bring closer together a number of offices serving MIT students, faculty, and staff. The effective date of the change was on March 1, 1980, when John M. Wynne took early retirement from his post of Vice President, Administration and Personnel, a post in which he had served with distinction for the past 13 years. Mr. Wynne was responsible for personnel, admissions, financial aid, and placement; he was also the Institute's Equal Opportunity Officer and was responsible for liaison with legal services and for privacy policy throughout the administration.

As a friend and associate of John Wynne for the past two decades, I am one of many people who can speak about his contributions to MIT. John's great wisdom, his effectiveness, and his selfless dedication to the Institute are matched only by his gentle and friendly manner, his subtle sense of humor, and his unique approach to complex problems characterized by a remarkable blend of resolve and flexibility.

Under his leadership, the Institute's commitment to equal opportunity was formed and articulated, and our Affirmative Action program was put into place and made to work. Personnel services were reorganized to improve response and service to all staff groups throughout the campus. More recently, our appointment and salary structures for research, administrative, and support staffs were revamped and rationalized, as were legal services and our internal policies on privacy and conflict of interest. Indeed, the whole complex of MIT policies and procedures, on all aspects of institutional life and work, was patiently studied by John in detail, improved and codified into a revised *Policies and Procedures* guide which was published in 1979.

The annual reports which follow account for the departmental activities in Student Affairs, Athletics, Admissions, Student Financial Aid, Career Planning and Placement, Personnel, the News Office and Campus Information Services, the MIT Press, and the Quarter Century Club. Dr. Isaac Colbert, the Institute's Assistant Equal Opportunity Officer, has reported on the highlights of the MIT Affirmative Action program.

There are also reports from the Undergraduate Research Opportunities Program, the MIT Council for the Arts, and the Institute's Information Processing Services. These activities have reported directly to the Office of the President and Chancellor. In the future, both IPS and UROP will report to the Office of the Provost.

Last year at this time, I reported in great detail on the review and reorganization of the Office of the Dean for Student Affairs, and on our search for a new Dean to assume this senior policy-making and administrative post at MIT. I am happy to report that Dr. Shirley McBay took over these responsibilities in April 1980, with enthusiasm, a fresh point of view, and a seasoned hand from experience of 20 years in academic work and, more recently, in government service at the National Science Foundation.

I also am happy to report that a search to succeed the Director of Athletics Professor Ross Smith, came to a happy conclusion with the appointment of Royce Flippin as Professor and Director of Athletics and Head of the Department, beginning in August 1980. Professor Smith led the Department of Athletics for the past 19 years, the longest recent service on record as a department head. During this period Athletics at MIT experienced major and unprecedented growth in programs, participation, facilities, and service to the students and to everyone in the MIT community. Professor

Flippin comes to MIT from a successful career as Director of Athletics at Princeton University during the 1970s, and as a business executive, both before and after his service at Princeton.

There are two final points I wish to make in closing this introductory statement of the year's annual report. First, I would like to state what I think is the mission of the segment of the administrative services for which I am responsible: in a large institution the success of services in support of people rests on our ability to welcome and encourage diversity of personal backgrounds, interests, and points of view, on one hand, while working hard to develop a cohesion of purpose and a close collaboration in addressing problems and in meeting continuing and emerging needs. Last spring and during the summer we began working as a group to bring our diverse perspectives and points of view to bear on the administration of our areas and on our contribution to the formulation of MIT policies with a special concern for their effects on MIT people.

The second point I wish to make is simply an expression of thanks to all of the people, and especially my close associates, who have helped and continue to help in the transition and the complex tasks of our office. I would like to single out two managers in our area, Kathryn W. Lombardi, Manager of Campus Information Services, and James J. Culliton, Director of Personnel, who, in addition to their management duties, serve also as senior assistants to the Vice President; also, Nancy K. Lombardi, my Staff Assistant for several years, who is now Administrative Officer in the Office of the President; and, last but not least, my closest office associate and Administrative Assistant, O. Jean Messier.

It is, in the end, the quality and the value of working with these colleagues that makes the job worthwhile.

CONSTANTINE B. SIMONIDES

Affirmative Action Program

In the employment of minorities, the past year witnessed uneven performance. Overall employment goals projected for July 1980 reflected the expectation of significant shrinkage of hiring opportunities, as well as the failure to achieve goals set for the previous year. As of April 1980, minorities comprised eight percent (86) of the faculty, with a goal of six percent. Underrepresented minority groups did not account for the goal over-reach in this category. In the category of other academic staff, minorities comprised 18 percent, with no increase from the previous year in the representation of blacks but a small increase in Hispanic representation. Minorities comprised five percent of the administrative staff and nine percent of the research staff, meeting employment goals for the latter category. The goal of seven percent was achieved for minority employment in the exempt categories. As in the past, the support and service staffs continue to show substantial minority presence, with, respectively, 10 percent and 17 percent representation.

The employment of women at all levels of Institute operations continues to show progress. As of April 1980, women represented eight percent (88) of the faculty and 21 percent (374) of the academic staff. As 46 percent (319) of the administrative staff, women have made substantial gains over the past year. In research staff categories, women comprise 24 percent of the technical staff jobs and 43 percent of the administrative positions -- again, an increase over previous levels of representation. The exempt (75 percent), support (85 percent), and service (29 percent) categories continue to employ women in substantial numbers. The past year has shown, encouragingly, a broadening of the representation of women into areas important to the academic and research endeavors at MIT.

The past year's activities centered around the report and recommendations of the Equal Opportunity Committee to the Academic Council. Concluding its "affirmative action profile" of the Institute for the years 1970-79, the Committee recommended numerous steps that departments can undertake to increase minority, especially black, representation. The centerpiece of the report was the notion of an "active search" and a series of suggested means to build word-of-mouth contacts and other avenues of rapport within minority professional communities. Following a series of discussions in the Academic Council and with department heads concerning the Committee report, President Jerome B. Wiesner and Chancellor Paul E. Gray issued to department heads in April a memorandum outlining suggestions for the active recruitment of black and other minority faculty. Consistent with these suggestions, the Serious Search policy and related procedures as expressed in the MIT Affirmative Action Plan have been modified. Also, Institute officials involved in the ongoing implementation of affirmative action policy have become more visible as information resources to assist in the search process. We are encouraged that the renewed commitment to affirmative action together with policy and procedural innovations will be reflected next year and beyond in increased racial diversity throughout the Institute.

Other substantive activities during the past year have direct implications for the Institute's compliance status with regard to equal opportunity and affirmative action regulations. In November, and again in February, the Department of Labor's (DOL) Office of Federal Contract Compliance Programs (OFCCP) initiated its compliance review of the Institute. Although this review currently appears to be in abeyance, we expect the OFCCP team to return to the campus to complete its examination of our plans and of our good-faith efforts to achieve goals. We are concerned that the current round of updates of our plans has proceeded without the benefit of OFCCP input, especially since DOL regulations and enforcement history differ substantially from those of the previous Federal compliance agency. However, we remain confident that, in technical adherence to the regulations and in the quality of our efforts, the Institute is in compliance with Federal requirements.

During the past year, the Institute's major Affirmative Action Plan and the plans for the Handicapped and for Disabled and Vietnam Era Veterans were reviewed and updated. The Affirmative Action Program for Disabled Veterans and Veterans of the Vietnam Era was published in *Tech Talk* in June; the Affirmative Action Plan for the Handicapped is expected to be published in late July, as soon as the updated copy of the Guide for the Handicapped is completed; and the MIT Affirmative Plan will be published in September as a *Tech Talk* supplement.

A significant new development to enhance our efforts on behalf of the handicapped will be the formation of a Handicapped Advisory Committee. This group will recommend policies designed to improve the delivery of services to handicapped employees and students.

In addition to the substantial activities of the past year, a number of significant staff changes occurred. Dr. Isaac M. Colbert, formerly Senior Consultant/Trainer in the Office of Personnel Development, is now the Assistant Equal Opportunity Officer, replacing Cheryl R. Prejean, who was on loan to MIT from the Department of Labor.

On March 1, 1980, John M. Wynne, Vice President, Administration and Personnel and the Institute's Equal Opportunity Officer, left MIT to pursue a new career. His departure ended an era. Under Mr. Wynne's knowledgeable and enlightened administrative guidance, the Institute erected an organizational and policy framework for equal opportunity and affirmative action that, in our view, remains unparalleled in higher education. Our equal opportunity and affirmative action efforts have benefited immensely from his insight, his good judgment, and his concern for people. With Mr. Wynne's departure, Constantine B. Simonides, Vice President of the Institute, assumed the duties and responsibilities of the Equal Opportunity Officer.

ISAAC M. COLBERT

Dean for Student Affairs Office

The plans reported a year ago for the reorganization of the Office of the Dean for Student Affairs (ODSA) led to substantial changes in organization and operation during the past year. Much is yet to be done but much has been accomplished.

Of the four sections of the ODSA, the section for Undergraduate Academic Support (UAS) has undergone the largest change. Formerly the Office of Freshman Advising, its responsibilities have been broadened to become an academic information center for all undergraduates and their advisors, to provide operational support and liaison for the departmental undergraduate offices, and to provide direct assistance to the interconnection of students with the Committee on Academic Performance and with the Registrar's operations.

The Student Assistance Services (SAS) section, while still emphasizing the counseling of individual students and their operational support when leaving for a time or returning, has welcomed the addition of the Office of International Students. With the increased SAS efforts in support of graduate student needs, the complementary effort with international students, most of whom are at the graduate level, gives a solid base on which to build. The SAS also has continued to improve and focus the support of programs for minority students and women.

The Student Activities section has continued operational support and coordination for the many diverse student activities, organizations, and programs. Increasingly promising efforts at encouraging growth in student leadership, especially at the graduate level, have been an important emphasis in the past year.

The section for Residence Programs has continued support of the Institute Houses with increased emphasis on programs and leadership. The support of the operations of the independent living groups has been expanded and clarified. Increased attention has been focused on the overall housing needs of graduate students.

The staff of the ODSA is encouraged by the progress of the past year. The increased awareness of and emphasis on the wide range of needs of graduate students is long overdue and promises difficult but rewarding improvements. The ongoing construction of the new dormitory on the West Campus will reduce in fall 1981 the present inequities in housing for transfer students, returning students, and crowded freshmen. The major review of on-campus dining promises to reverse a downward trend of some years standing. The growing effectiveness of the new Committee on Student Affairs can provide focus and support for the ODSA efforts on behalf of students.

Following an extended search, a new Dean for Student Affairs, Dr. Shirley M. McBay, arrived on campus in mid-April. She will not lack for challenge in these times of tight budget with increased expectations depending greatly for fulfillment on the more effective operation of the ODSA and its counterparts throughout MIT.

With but little regret I have given up my responsibilities as Acting Dean and happily turned once again to working informally with individual undergraduates as a teacher, advisor, and learner. My stint as Acting Dean was made possible by the sensitive, enthusiastic, and responsible efforts of the entire staff of the ODSA and by the close rapport I enjoyed with Vice President Constantine B. Simonides.

ROBERT L. HALFMAN

UNDERGRADUATE ACADEMIC SUPPORT

The past year was the first year of operation for the Undergraduate Academic Support (UAS) Office (formerly the Office of Freshman Advising). As discussed in last year's report, this section of the Dean's office now includes the Preprofessional Advising and Education Office (under the direction of Dean Susan Houpt) and the administrative support for the faculty Committee on Academic Performance (CAP) provided by Jane Dickson. In addition, the administration of the advising program for undesignated sophomores has been transferred to the UAS. The combination of administrative support of the CAP and the new and continuing services of the rest of the UAS has served to provide many students and faculty easy access to the sort of academic information and advice they require but so often find elusive. We have all observed an increase in the number of upperclass students who are taking advantage of the centralization of the academic information services, and have taken steps to encourage these visits. For instance, in cooperation with the Registrar's Office, we are now serving as a drop-off center for registration and address correction cards, petitions, and registration material. We hope to expand our cooperative services in the future.

An updated version of the "CAP Guide to Undergraduates and Faculty Advisors" will be completed this summer by Ms. Dickson.

Freshman Advising Program

The primary counseling of freshmen is done by approximately 260 advisors (faculty, staff, and graduate students) who voluntarily provide this important contact with an adult who knows MIT, who can help the freshmen find out what they want to know, and who can provide some perspective on the first-year experience. The table below shows the affiliation of the advisors as of July, 1980, and compares it with previous years:

	<u>Faculty*</u>	<u>Staff</u>	<u>Graduate Students</u>
1980-81	143	81	16
1979-80	123	91	23
1978-79	133	70	26
1977-78	136	72	40
New Advisors	33	7	3

(*includes lecturers and instructors)

Since we had observed a steady decline in the number of faculty serving as freshman advisors over the past few years, we made an effort this spring to talk individually with each of the department heads about the program and about our need for their support of it. This effort stemmed in part from comments we have received from the freshmen themselves who have related the need for more career-oriented guidance from faculty in the various academic fields. We feel these visits were worthwhile, even in those cases where we were unable to obtain a greater commitment to increasing the advising ranks with more faculty. We learned a great deal about the structure of the individual departments, their problems, and their impressions of our office. These contacts should help us with future efforts; we attempted to let the department heads know that our office was established to assist them.

We continue to have an abundance of undergraduates applying for the "associate advisor" positions. These students are a critical component of the advising system, in that they provide current information on the academic and social realities of undergraduate life at MIT.

The experimental Baker House advising program, which matched seven freshman advisors with approximately 35 freshmen in Baker House, met with some success during its first year. The faculty advisors did get more involved with the students and activities in the living group, although not at the anticipated level. The advisees were especially positive about the informal availability of the associate advisors in their living group. The major problems encountered during this first year were administrative in nature; the UAS has offered its services to the Baker advising coordinators to remedy these problems and to help with programs they may plan throughout the year.

For the past two years, the ad hoc faculty Committee on Freshman Advising, under the chairmanship of Professor James Melcher, has provided wise counsel on policy matters for the office. As part of the general reorganization of the ODSA, a permanent faculty advising committee, the Committee on Student Affairs, was formed. The "academic subgroup" of that committee, under the chairmanship of Professor Arthur Mattuck, has been fulfilling the role previously taken by the Committee on Freshman Advising.

The amount of personal counseling done by our section of the ODSA has decreased. We continue to discuss problems with freshmen and other students, and we give a good amount of academic advice, but refer most to the SAS section when more intensive counseling is called for.

Fourteen freshmen withdrew for a variety of personal reasons during the academic year. Sixteen additional freshmen were required to withdraw for at least one term because of unsatisfactory academic performance. The table below summarizes the number of formal warnings of unsatisfactory performance given by the Committee on Academic Performance ("CAP Warning") or the more informal letter from our office suggesting that the student review his or her performance. Also shown is the number of Required Withdrawals.

	<u>Required Withdrawals</u>	<u>CAP Warnings</u>	<u>UAS Letters</u>		<u>Required Withdrawals</u>	<u>CAP Warnings</u>	<u>UAS Letters</u>
January '80	1	43	33	June '80	15	63	60
January '79	1	45	38	June '79	12	63	49
January '78	3	38	39	June '78	10	75	41
January '77	1	30	29	June '77	17	47	32

We have been involved in several efforts to help students and the departments find a good match as students select a Course of study. One component of that endeavor has been the "Trailblazing" seminar -- a half-day meeting between students and alumni jointly sponsored by our office, the Undergraduate Association, the Alumni Association, and the Career Planning and Placement Office. The seminar was created in an effort to demonstrate to students that careers do not usually follow straight, well-determined paths. It is interesting to note that a similar symposium -- offered by the School of Science -- was spawned this year in response to a feeling that Trailblazing gave too much emphasis to careers in engineering fields. That, too, was a worthwhile symposium (to which we lent assistance), and we hope that both events will continue to contribute to the student's perspective on career choices.

Another aspect of our activities was the second annual distribution of a questionnaire asking freshmen to state the factors which were of importance when they selected their sophomore major. We plan to follow students through their MIT career (and perhaps beyond) as they change their goals in an attempt to understand the factors leading to these changes. It is interesting to note that approximately 30 percent of last year's senior class changed their major department between the end of their first year and graduation. Currently, we are finding that the student's initial choice of major seems to be mainly governed by decisions made before entering MIT.

Since the *Freshman Handbook* is the main information document for both incoming freshmen and their advisors, the preparation of this annual publication continues to occupy a significant portion of staff time during the spring term. We wish to express our thanks to the many faculty, staff, and students who assisted with this year's edition.

Preprofessional Advising and Education Office

The Preprofessional Advising and Education Office continued to provide a focus for students who are interested in careers in medicine and law.

In September, meetings with freshmen acquainted them with the advisory services of the Pre-medical and Prelaw Councils as well as services available from the Preprofessional Advising and Education Office. An informal meeting was held between members of the Prelaw Advisory Council and students interested in a legal education. This meeting proved to be a mechanism which lowered the threshold for students to approach these advisors throughout the academic year. In October, Dr. Oglesby Paul, Director of Admissions at Harvard Medical School, spoke with medical school applicants about the nature and format of the medical school interview. That same month, sophomores were told of the planning necessary for a medical education. In March, members of the Council met with students who will be attending medical school next year. Discussion focused on criteria for selecting among medical schools. Also, a session was held to acquaint MIT students with the Medical College Admission Test (MCAT). In April there were two meetings for those students who will apply for admission to medical or law school for the class entering in September 1981.

Representatives from one medical school, the Army, and the National Health Service Corps and 11 law schools visited MIT during the year. They met with students as well as members of the Advisory Councils. These sessions benefit the Advisory Councils and the students as well as the professional schools in that they provide a source of helpful information.

During Independent Activities Period (IAP) the Preprofessional Advising and Education Office sponsored or co-sponsored a number of offerings. These included: "So You Want to Be a Lawyer," co-sponsored with Professor J.D. Nyhart, of the Sloan School of Management and Chairman of the Prelaw Advisory Council; "A Brief Introduction to the Law," co-sponsored with Professor Jeffrey Meldman of the Sloan School of Management; and "Energy -- Related Issues in Modern Medicine: Pollutants" with Professor Bernard S. Gould of the Department of Biology.

During this past year Dean Houpt assigned 100 members of the Class of 1982 to members of the Premedical Advisory Council. It is anticipated that several more members of the Class of 1982 will be assigned to advisors in September. Last year at this time, 73 individuals of the Class of 1981 had been assigned to advisors; at the present time, that number has grown to 156.

Dean Houpt wrote letters in support of 45 applicants to law school, seven fewer than last year; 27 letters were for currently registered students and 18 letters for former students.

The Undergraduate Seminar Program

The Undergraduate Seminar Program showed an increase in the number of offerings in the fall semester (from 47 to 50) and a decrease in the spring semester (from 37 to 34). The large number of students who choose to participate in this program continues to indicate that these seminars provide an important addition to MIT's curriculum: 741 students (527 of whom were freshmen) participated in a fall term seminar; 512 students (of whom 244 were freshmen) participated in seminars in the spring. Since enrollment in undergraduate seminars continues to remain high, the problem of oversubscription in the program has become an increasing concern.

This spring, we wrote a special letter to department heads to alert them to the steady decline of faculty participation in the Undergraduate Seminar Program. We also discussed the role of the seminars in the undergraduate curriculum and the importance of continuing faculty involvement this spring. We found that department chairmen are very aware of the unique nature of the seminar experience for both the faculty member and the students in the class, but that, for many, the burdens on time often preclude their being able to contribute to these sorts of "extra" activities.

Professor Michael Driscoll has continued as faculty chairman of the Undergraduate Seminar Program, and Peggy Richardson as executive officer.

Undesignated Sophomore Program

Continuing the downward trend of recent years, about 30 percent fewer sophomores chose to use the undesignated category this spring rather than to declare departmental affiliation. Forty-five volunteer advisors drawn from faculty and staff were needed to provide a reasonable match of interests with the 74 undesignated sophomores at the beginning of the fall semester, and the 42 in the spring. Six years ago, 68 advisors were needed for the 237 sophomores in the fall and 135 in the spring.

To a certain extent this decline in the number of undesignated sophomores may be attributable to the fact that as undesignated sophomores, these students lack an undergraduate "home" and, in many cases, a faculty advisor dedicated to their whole career as an upperclass undergraduate. Next year, we hope to increase the number of faculty advisors in the undesignated sophomore program in areas that are common to the interests of undecided sophomores, while at the same time to communicate to these students that they should consider the UAS as their pre-departmental office.

Staff

Staff within the UAS continue to serve as ex officio members of the Committee on Curricula and the Committee on Undergraduate Admissions and Financial Aid. We hold membership on the faculty/staff advisory committee to the Office of Minority Education and the IAP Administrative Committee. We also attend meetings chaired by Dean Robert Alberty for faculty teaching science requirement subjects taken by many freshmen. Staff members meet regularly with the Committee on Student Affairs academic subgroup, a source of wise counsel. We thank them for their involvement.

Eric Sklar, Class of 1981, was student coordinator for the 1979 Residence/Orientation Week. Jeffrey Solof, Class of 1981, is in the process of coordinating these efforts for the fall of 1980. A large number of undergraduates volunteer their assistance for this planning.

Two staff changes accompanied the shift in the direction of the UAS. Dean Bonny Kellermann moved to Student Assistant Services in order to devote more of her time to counseling of individual students. Ms. Richardson joined the office as executive officer of the UAS. She formerly was director of the Undergraduate Office of the Physics Department and brings with her first-hand knowledge of the issues confronting upperclass students.

Alan Lazarus submitted his resignation as director of the UAS effective June 1980. With great difficulty, he finally arrived at the decision to return to physics full-time, and he leaves the UAS with much appreciation to its concerned staff who are dedicated to the support of MIT students, faculty, and its academic programs.

SUSAN HAIGH HOUP
ALAN J. LAZARUS
PEGGY RICHARDSON

STUDENT ASSISTANCE SERVICES

As part of the ODSA reorganization, Dean Bonny Kellermann has moved into Student Assistance Services with a major responsibility for counseling but bringing with her special responsibilities for supporting the faculty Committee on Discipline and for providing a focus for the support of handicapped students. She is a charter member of the Massachusetts Association on Handicapped Student Service Programs in Postsecondary Education and through a program at MIT in April helped members learn about the research at MIT in rehabilitative engineering.

A most welcome addition to the SAS is the International Student Office with Dean Eugene Chamberlain and his staff. The operational support and counseling provided for the international students complements and supplements effectively the SAS services for all students, especially at the graduate level.

Other efforts in the SAS in support of graduate students have been focused by Dean Holliday Heine as part of the ODSA effort to better meet their many needs.

Although not reported on specifically in the following sections, a key service for responding to student emergencies is often called into action. Robert Holden as dean-on-call on nights and weekends often plays an important facilitative and coordinating role as do other deans in primarily daytime emergencies. The responsiveness and sensitivity of the many cooperating medical, police, residential, and academic personnel is a major asset to MIT.

Advising and Counseling

The advising and counseling of students remains one of the most important activities of the SAS. Three deans devote the majority of their time to counseling and two deans share the responsibility through a commitment of half of their time; in fact all members of the ODSA often find themselves in a counseling role.

Last year nearly 700 undergraduate students either withdrew or were readmitted through the SAS. In almost all cases a dean spent a substantial amount of time with these students as they formulated their plans. Because of the recognition of the growing importance of leave-taking and returning, the SAS under the leadership of Deans Holliday Heine and Bonny Kellermann formulated a flexible but formal leave of absence policy that has now become MIT policy.

Despite some reduction in counseling resources, the staff of the SAS had slightly more than 2,400 substantial conferences with individual students. Part of the small increase from the previous year was due to the number of graduate students using the services of the office. We expect this number to continue to grow. The number of conferences is, in itself, slightly misleading since each conference might well involve contact with an advisor, members of the family, professors, and those involved in other areas of student services.

The SAS staff works closely with the Medical Department in general and specifically with the Psychiatric Service. Regular meetings with the psychiatrists allow for professional interaction beneficial to both groups. Through contact with Dr. Edward Rendall, we have also broadened and improved our relationship with other areas of the Medical Department. We are assisting in the process of updating and rewriting *SEX*, the student handbook on sexuality and related matters which will be distributed to students at Wellesley as well as at MIT.

In some respects, it may be argued, the ODSA has assumed a more active stance in regard to counseling needs. We have helped to develop and support a number of groups designed to reach students with information and services that may prevent problems. These groups include the Human Relations Group which met regularly after IAP and focused on majority-minority issues. More than 40 members of the community (students, faculty, and staff) were regularly involved and the program will continue next year. The program effectively broadened our interaction with the minority community, and supported the work in that area being done by Dean Mary Hope and other members of the staff. Study skills seminars were also initiated under the leadership of Dean Kellermann and we expect that this program will grow. Drawing heavily on the experience of Wellesley College's A+ program, groups of students were trained to offer seminars discussing time management, note-taking, writing papers, problem solving, and exam preparation. Approximately 40 students participated in one or more of these presentations.

The continued success of Nightline, a peer help group, answering student questions at night over the phone has been supported and encouraged by all members of the staff and specifically by Deans Robert Halfman, Robert Randolph, Deans Chamberlain and Kellermann, as well as members of the chaplaincy, psychiatric service, and social work services. The number of inquiries coming into Nightline increased this year and on several occasions, they were the first

contact with a significant student problem that was then steered to a resource where it could be resolved.

Nightline, Study Skills Seminars, and the Human Relations Group have allowed us to broaden our counseling network while maintaining present staffing levels. It is clear that there is much more that can be done with groups especially as graduate students, international students, and women see our counseling services as a viable form of support while they are here at MIT.

INTERNATIONAL STUDENTS

In September 1979, MIT enrolled about 1,600 international students representing 94 different nations. They constituted 29 percent of the graduate population, 9 percent of the undergraduate population, and nearly 19 percent of the entire student body. Of the international students, nearly one-quarter were women.

In the United States as a whole in 1978-79 there were 263,938 international students studying in 2,752 institutions as reported in *1978-79 Open Doors* published by the Institute of International Education. This represents continued growth through most of the past 25 years but is still only 1.5 percent of all students in higher education. Two interesting comparisons of national and MIT figures are tabulated below.

Distribution by World Regions Versus Percentages at MIT

(A Limited Sample)

	<u>Open Door/IIE</u>	<u>MIT/79</u>
Africa	12.9%	5.1%
Asia	55.7%	35.9%
Europe	8.2%	21.7%
Latin America	15.6%	12.0%
North America	5.9%	9.2%

Academic Interests of International Students Versus MIT

	<u>Open Door/IIE</u>	<u>MIT/80</u>
Engineering	28.8%	48.7%
Business and Management	16.8%	29.4%
Natural and Life Sciences	9.2%	27.6%
Fine and Applied Arts (Architecture and Urban Studies)	5.3%	33.8%

By 1979 there were reported to be some 150,000 citizens of Iran in this country. Among these were some 50,000 students enrolled in secondary schools, two-year junior colleges, and four-year degree-granting institutions. Events in California in the spring of 1979 among a limited number of Iranian students clearly indicated that the Immigration and Naturalization Service (INS) had minimal information on matching these students to the institutions in which they were enrolled.

INS then embarked upon a re-certification program designed to clearly identify Iranian students with institutions to determine full-time registration and the maintenance of proper status. To many students, it was a program not without fear. This program, accompanied by the public attention to the revolution/hostage situation, may in time be regarded as a turning point in inter-nation educational affairs in the United States, and it demanded major attention during the first term of the academic year. The attending financial problems for many of the students sponsored by institutions in Iran further complicated the reporting process. The continuation of enrollment for students holding private funds in Iran was also often in jeopardy. In many cases the graduate departments came to the financial aid of their Iranian students by providing research or teaching assistantships. A policy for providing emergency loans was approved by the Academic Council. The records clearly reflect that only a very small fraction of Iranian

students who might have sought help from this loan program actually did so. Pooled resources outside of the Institute were apparently drawn on for support. Further, it can be observed that some dollars for tuition and maintenance allowance continued to arrive from responsible sources in Iran, both for private and sponsored students.

The Iranian students at MIT are a responsible group of young people. One may not always agree with their stance on the troublesome issues involved -- the hostages -- but most of them have managed both their academic and social matters as well as financial affairs with reasonableness that muted the intense personal pressures which are still apparent for them as the term comes to a close. The outcome of the divisive events of April and May 1980, involving the directive from the President of the United States calling for the denial of normal extensions of stay for Iranian students or research staff with fixed dates for normal renewals of their presence in their respective programs will be reported by this office in 1981.

Three additional comments need to be made: first, the civility of the MIT community towards the Iranian students has been markedly free of rancor. Secondly, the faculty as well as the administration has sought to protect the interests and privacy of the students at all times. Finally, the substantial assistance of many people representing the Office of the Dean of the Graduate School, the Financial Aid Office, and Student Accounts in counseling and formulating policy is greatly appreciated.

Based upon the records of this office, one can trace the initial admission of a student from China back to the year 1901. Enrollment increased rapidly from 1910 to 1920 peaking at 60 in that year. By the mid-twenties, however, the enrollment of students from China had declined so that it never exceeded 30 in any one year up through 1944.

However, in September 1979, after a lapse of some 30 years, the Institute began again to enroll students from the People's Republic of China. Seven were enrolled for the autumn term, others arrived at the beginning of the spring term in February 1980. (In addition, there were 30 visiting scientists invited by individual members of the faculty to participate in on-going research programs of various departments and laboratories.) Traditional methods of identifying courses of study, the grades acquired, and the applicants' ability to use the English language were in some cases simply not available. Typical US programs for testing an applicant's knowledge about a given field of study or level of competence in English are not now available in China. Hence, many of the new arrivals on campus needed intensive English language training. Often this training is taken in concert with their regular academic subjects. This instruction was ably carried on through the English language program administered by Professor Margery Resnick and her staff of instructors.

These conditions -- minimal information about academic programs and recognizable credentials as well as efficient training in English -- are apt to last well into the next decade. This will not stem the tide of applicants to MIT, nor their subsequent enrollment.

It has been the established custom of the staff of the Office of International Students to initially welcome and introduce students from abroad to the MIT community. This introduction is often assisted in an organized manner by experienced students as representatives of international clubs or associations on campus. The International Open House provides a common meeting place in September for students, staff, and their families who are new to MIT. This was organized jointly by Dr. Charlotte Schwartz, and Myra Rodriguez of the Medical Department, and the International Student Advisor. Also, some 400 MIT alumni families continue to volunteer their assistance to new arrivals through the Host Family Program. Mrs. Jay Forrester has completed her last year as chairperson of this program which was initially organized in 1946.

MINORITY STUDENTS

Support activities for minority students continued to be a primary focus of the SAS. Discussions with individuals and small groups of students, alumni, parents, faculty, and staff continue to serve as an important source of information concerning the minority students' educational

experience at the Institute. Academic progress continues to be monitored. Students are encouraged and assisted in utilizing academic resources more effectively.

The academic term for 1979-80 began with an ambitious and well-planned orientation program for minority freshmen designed to emphasize and supplement information and resources available to students at MIT. Sessions were well attended by freshmen and upperclassmen.

The 1979 Black Students Conference on Science and Technology was held during the second weekend of September 1979, to try to inspire and motivate students at the beginning of the fall term rather than in the middle of the spring term. The conference theme was "The Pursuit of Excellence in Business, Science, and Technology." Students from the Mario Umana Harbor School of Science and Technology were the guest participants for the High School Conference presentation and display entitled "A Glimpse of African-American Contributions to the Development of Science and Technology." This presentation, and "A Look at Civil Engineering," and a question and answer session comprised the activities. Guest speakers were Eugene Callender, President of Callender Consulting Engineers of New York City; Kenneth I. Guscott of Guscott Associates; and Raouf Abdullah from the World Community of Al-Islam. Dr. Ronald McNair, Class of 1976, CB Astronaut-Johnson Space Center, was the keynote speaker for the conference. Workshop topics were: "Career Opportunities in the 1980s," "American Minorities in the International Business Market," "Black Women in Science, Technology, and Business," and "Problems, Prospects, and Promises of Doing Business in the 1980s." Conference sponsors were Bell Systems, Hewlett Packard, Inner City Broadcasting, International Business Machines, Procter and Gamble, General Motors, Exxon, United Technologies, and Computer Interactive Services.

The Minority Undergraduate Discussion Groups have become a viable forum for student self-expression and exposure to positive role models in all areas of science and technology. Programs have been varied and designed to meet specific student interests. The Undergraduate Women's Problem Sessions have focused upon specific and individual needs as indicated by students.

On- and off-campus conference attendance continues to be encouraged. Students attended the North Atlantic Leadership Conference for Minority College Youth, the National Convention Society of Black Engineers held at Stanford University, and the Human Relations Workshop here at MIT.

The Alpha Kappa Alpha Sorority Holiday Soiree has become an annual affair, and the McCormick Penthouse Christmas Party for students remaining on campus during the Christmas holidays was held again this year.

The Minority Student Caucus was organized to increase communication and improve the coordination of activities between student groups and the Office of the Dean for Student Affairs. The Caucus is composed of officers from all minority groups at MIT.

The regional officers of the MIT Black Alumni convened this spring to plan activities to improve the support structure for minority students. This alumni group is coordinated by Kenneth Armstead, Classes of 1976 and 1978.

Ten internships for freshmen were established by the Exxon Company. Corning Company Corbest Scholarship Awards were awarded to two minority freshmen.

A total of 47 minority undergraduates received bachelor of science degrees at the 1980 Commencement. The 47 students include 32 African-Americans, six Mexican-Americans, three Puerto Rican-Americans, and six Spanish-Americans. Four African-Americans and one Spanish-American student received two degrees. One African-American student completed the degree program in three years.

Dean Mary Hope attended the first scholarly research conference for black women under the auspices of the National Council of Negro Women held in Washington, DC in November 1979.

WOMEN'S PROGRAM

As a direct result of the expressed needs of women students brought forth in the recent review of the ODSA, Dean Heine was authorized to organize a group of women staff and faculty last summer to make a recommendation concerning coordination of activities of interest to women students, both graduate and undergraduate. The outcome of our discussions was to propose the creation of a new position, in the ODSA at the exempt level, of Coordinator for Women Student Interests, and the establishment of a complementary, presidentially appointed committee of faculty, staff, and students to act in an advisory capacity for women student interests. Emily Weidman was chosen for the position of Coordinator, beginning work in mid-February. The Advisory Committee, under the direction of Professor Mildred Dresselhaus, had its first meeting in May and will be in full operation next year.

In November, Dean Heine sponsored with the Radcliffe Forum and the Career Services Office of Wellesley College, a conference at MIT entitled "Science and Technology in the Business World: Opportunities for Women." This one-day conference, attended by approximately 200 high school, undergraduate, and graduate women, brought together panelists from Washington, DC, to upper New York State for the discussions.

The Ad Hoc Committee on Women's Admissions proposed to the Committee on Undergraduate Admissions and Financial Aid a recommendation for a substantial change in MIT's program for recruitment of women students towards greater emphasis on the development of potential students. In addition, the Ad Hoc Committee carried out other support activities to the admissions process including organization of the third annual telethon to admitted women. Participation in the telethon by women undergraduates of the Association for Women Students (AWS) as well as letter writing to admitted women continue to be an integral part of the women's admissions program.

In cooperation with AWS, the MIT Women's League this year sponsored a supper to provide an opportunity for women students to meet wives of faculty members who have careers of their own, in order to supplement the MIT women faculty and provide a larger number of adult women to be contacts or role models for the students.

The Society of Women Engineers, in its first full year of operation, was a spectacular success, especially in its production of an Industrial Fair, attended by 100 companies and 600 male and female students, and a follow-up banquet for the company representatives and Society members. The contribution of the group throughout the year was recognized by a Compton Award to the Society and a Stewart Award to President Barbara Johnston for the organization of the Industrial Fair.

FOREIGN STUDY

The Junior Year Abroad and Domestic Year Away programs continue to be valuable alternatives for those students who wish to broaden their undergraduate experience, whether in another culture or on another campus. This year 25 students (an increase of 11 over the previous year) enjoyed a term or two on the Junior Year Abroad and chose programs of study in Poland, France (5), Austria (4), England (6), Scotland, Germany (3), Israel (3), Belgium, and Ireland, with one student spending the fall term 1979 in Vienna and the spring term 1980 in London. Six students participated in one or two terms of Domestic Year Away study at these American institutions: Michigan State University, Vassar College, Georgia Institute of Technology, Harvard University, University of Oklahoma, and Brown University.

Information and materials on summer study programs, international student identification cards, passports and visas, and work and travel abroad as well as accredited term or year programs of study were provided during this academic year to undergraduate and graduate students, faculty, and staff members of the MIT community during 400 visits.

Representatives from Denmark's International Study Program in Copenhagen, the London School of Economics, the Beaver College (PA) Programs in England, the Institute of European Studies in Chicago, the Monterrey Institute of Technology, and the State University of Mexico visited MIT to discuss their current programs and the possibility of future exchange arrangements. Katherine C. Cutting attended the annual meeting of the Council on International Educational Exchange and the regional meeting of the National Association for Foreign Student Affairs held in New Hampshire.

Appropriate new faculty and staff contacts were made and old ones strengthened, increasing and improving our ability to give students an opportunity to make thoughtful comparisons of themselves and their studies at MIT and in another academic environment.

DISCIPLINARY CONCERNS

Among the most frequent situations which came to our attention (nine times) were incidents which were intended to be harmless pranks but caused safety concerns, abused or inconvenienced individuals, or destroyed property. One of these cases, which involved a student who had violated probation, was referred to the Committee on Discipline (COD). Also referred to COD were five of the nine cases involving theft, two of the six cases of violent or abusive behavior, and two of the four cases of academic dishonesty.

Cases heard by the COD resulted in three decisions for suspension, three for formal probation, one for Dean's Office probation, and one reprimand. Two cases are scheduled to be heard by COD at a later date. Cases which were resolved by a Dean had the following results: in 14 cases, students were placed on Dean's Office probation. Students in four of these cases were also expelled from the dormitory. The remaining cases resulted in discussions which led to a warning or no action if the charges were unsubstantiated. In addition to the cases which were formally brought to our attention, a number of discussions were held with members of the community (students, faculty, and staff) about disciplinary problems which were then resolved through informal channels.

Dean Kellermann and Dean Robert Sherwood met periodically with chairpeople of dormitory judicial committees to continue to review the role played by the committees and to keep these individuals well informed about other options. Monthly meetings also were held for the chairman of the COD to meet with members of the staff involved with disciplinary concerns.

EUGENE R. CHAMBERLAIN
ROBERT L. HALFMAN
HOLLIDAY C. HEINE
MARY O. HOPE
BONNY S. KELLERMANN
ROBERT M. RANDOLPH

STUDENT ACTIVITIES

For the fourth consecutive year, now an entire undergraduate generation, the twin themes of student social interaction and the quality of student life continue to dominate the concerns of Student Activities, Student Community Affairs, and Governance. These issues appear to have

much to do with how students view themselves, their personal development, and their expectations of the educational experience.

These themes were the special focus of a mini, one-day, Saturday conference in March where approximately 85 undergraduates gathered to discuss "Social Interaction, Alternatives, Experiences and Opportunities" from the perspective of athletics, activities, dormitories, fraternities, classes, and government. Following descriptive statements by representatives from these areas as to what was happening, four students eloquently expressed particular viewpoints concerning needs and opportunities. This occasion was organized by the Social Committee. These issues have arisen also, at the several meetings of the General Assembly of the Undergraduate Association and in the sessions of the Graduate Student Council. To deal productively with this groundswell some new communication structures and linkages may be necessary.

Social events and programs continued to flourish under the sponsorship of all segments of the student community. Handicapped somewhat by the necessity to close Kresge Auditorium for roof repairs in September, six months earlier than planned, many programs reassigned to smaller and frequently more informal spaces attracted enthusiastic student audiences who enjoyed being together. We are relieved to report that, as regards community events, the student community has responded responsibly to the change in the drinking age laws and to the guidelines and procedures that have been instituted relative to alcohol-related events, and that these have had little if any negative impact on social programming. The frequency of groups co-sponsoring social occasions also has increased during the year; while Olympiad 1980 involved new segments of the student community in organizing and planning this traditional spring weekend of events.

The re-establishment of the Undergraduate Association General Assembly has been a substantial accomplishment of the UAP-UAVP team of John Hakala and Charles Markham. This representative body of 80 met approximately nine times during the year in residential settings on both sides of the river. The initial organizational problems are being dealt with in first-rate fashion, and the Assembly promises to be both a method of voicing and formulating student concerns and an additional means of nurturing an informed student leadership. The Nominations Committee broke new ground this year by hosting with Vice President Constantine Simonides a series of luncheons during the Independent Activities Period which brought together faculty chairmen and members of the several faculty and presidential committees, graduate and undergraduate members of the committees, and other student leaders. The exchange of information between these working segments was of inestimable importance to all. In April, *The Tech* published in directory form the names of students on these and other committees. This was a helpful new way of assisting the student community in learning who its student representatives are.

The Graduate Student Council under the leadership of President Reynold C. Verret also has enjoyed a productive year. New working relationships with the Alumni Association were initiated at a luncheon in October when Claude Brenner, President of the Association, members of the Alumni Resource Committee, and the staff, met with graduate students to discuss the purposes and programs of the Association. Anne Gwinnett has joined the Council support staff as administrative assistant, replacing Pegg Hunter.

The number of recognized Student Activities remains constant at about 100. They continue, as formerly, to provide responsible outlets and opportunities for service, association, programming, and the cultivation and development of general interests and skills. The Activities Development Board, under the chairmanship of Professor Kenneth C. Russell, meets approximately eight times during the year and while making grants to activities for capital equipment also keeps up-to-date on the full range of these student organizations. We note with pleasure the establishment during the year of an MIT student chapter of the Society of Women Engineers.

Space utilization continues to be a major concern of the Student Center Committee scheduling officers, the Association of Student Activities Executive Committee, and the Graduate Student Council activities section. Program spaces in Kresge Auditorium, the Stratton Student Center, Walker Memorial, and Burton-Connor Dining Hall continue, in most cases, to be scheduled at prime-time capacity. Thanks to the good will and understanding of the community of users, and the beyond duty efforts of the Physical Plant operating staff, most projected programs can be accommodated, although frequently with compromises. The closing of Kresge Auditorium, beginning in September, imposed heavy burdens on musical and theatre programs. Although there was an heroic accommodative response from these groups, it was necessary in some cases

to curtail or reduce programs. The Schedules Office and Physical Plant staffs were equally heroic in finding and servicing alternate space. We look forward to a return to normal operations in the fall of 1980.

The MIT Chapel was in use for 13 memorial services, 58 weddings, 210 scheduled religious services, 27 special religious services, and 36 musical and theatrical programs. The Reverend Steven Henderson, previously a student intern, has joined the Religious Counselors group as the Southern Baptist representative.

Talbot House in South Pomfret, Vermont, continues to provide an outlet to groups who want to escape the hubbub of MIT. During 1979-80, 56 different groups comprised of 1,195 individuals stayed at Talbot House. These groups can be categorized as academic groups (29), living groups (11), clubs (10), and recreation groups (6).

Talbot House was utilized 45 weekends of the year. December, July, and August are the slowest months, while January and February continue to be the most popular. This was true this year despite the absence of appreciable snowfall. During IAP, eight different groups took advantage of the accommodations.

During the year the scheduling process was refined by Dean Susan Haigh Houpt and subsequently published in *The Tech*. The fee structure remained unchanged during this fiscal year, but escalating costs for routine maintenance and particularly for energy will force an adjustment next year.

ROBERT J. HOLDEN
SUSAN HAIGH HOUPT

RESIDENCE PROGRAMS

Institute Houses

During this past year, the issue of housing was once again of great concern to students, parents, faculty, staff, and alumni. It has become almost customary to start the year off with fraternities well-filled and more than 100 freshmen crowded into the Institute Houses beyond their normal capacity, and this year was no exception. The one striking difference this year, however, was the extremely strong reaction from the parents of those students who were in "limbo" during R/O Week, and who eventually did not get into the dorm of their choice. With the opening of the 352-bed "Next House" in the fall of 1981, the situation should improve markedly for undergraduates. In fact, for the first time, we should be in the position of being able to fully implement our housing policy of accommodating all freshmen, transfers, and readmitted students who desire on-campus housing and guaranteeing them eight terms of residency, without excessive crowding. (This is subject to maintaining our freshman class size at around 1,075 to 1,100.

The picture for graduate students is much more dismal. We are only able to accommodate 30 percent on campus, and the availability of affordable, convenient, and acceptable off-campus housing is becoming a thing of the past. We have no immediate evidence of the financial resources necessary to construct or purchase new graduate student housing, nor any immediate hope of cooperation from the cities of Boston or Cambridge to grant the necessary approvals if we did have the resources.

This past year was spent meeting with graduate students, graduate departments, graduate houses, the Graduate Student Council, the Committee on Student Affairs, and many others in an effort to identify the areas of concern and elicit some possible suggestions. Many of the possible alternatives will undoubtedly result in emotional reactions from some students, as we witnessed this past spring when thought was given to considering a study of switching the undergraduates in East Campus and Senior House with the graduates in Ashdown House.

Discussing the possibilities of putting a limit on the number of terms a graduate student may live on campus, or a quota system based upon a distance from MIT, or using some of the beds in Next House for graduates, has also produced a great deal of reaction, especially from those already enjoying on-campus housing. Nevertheless, a review of graduate housing policies and a long-range study of student housing are essential, as well as a clarification of administrative responsibility in the overall area of housing, particularly long-range planning and off-campus housing responsibilities.

Despite these overriding concerns, the past year can only be considered a very successful and rewarding one as far as the overall residence program in the Institute Houses is concerned. The house governments, judicial committees, commons committees, client teams, and Dormitory Council all worked extremely well. Burton House opened a new art gallery; Bexley Hall formed a committee which recommended the development of a garden area in the space between Bexley Hall and the sidewalk leading to the Student Center; Tang Hall is working on a music practice room, purchasing a new grand piano, and recreation equipment. Several dorms have developed painting projects in an effort to personalize their hall environment, in conjunction with the House Managers. Bexley Hall and Random Hall requested and received approval to open their houses to both men and women for next year. This was done partially in response to the request from women students to expand their selection of dorms with cooking facilities, particularly since McCormick will be a "commons house" under the new dining program. Dormitory Council also approved a policy which would greatly facilitate residents' switching from one dorm to another without losing seniority. Our students also responded very well to the new Massachusetts drinking age law and the new Institute procedures for parties with alcohol.

Because of the unprecedented rise in energy costs, the room rents for next year were raised an average of 13.8% (as compared with 5.6% last year). An energy clause was also written into the new housing contracts which allows for the possibility of a mid-year review of room rents if the cost of energy increases faster than we anticipated (as it did this past year, resulting in a large deficit in the operating budget).

One area of complete frustration this past year involved trying to develop administrative computer services for the residence system. Hopefully this situation will improve during the year.

Faculty and Graduate Students

The Faculty and Graduate Residents continue to be an invaluable resource to the Dean's Office and the Residence Program. We held several in-service training programs throughout the year involving Dean's Office staff, academic Deans, other student service departments, and covering topics ranging from cardiopulmonary resuscitation to a human relations seminar series. The latter involved faculty, staff, and over 40 students who discussed and monitored relations between ethnic groups on campus.

We were very sorry to learn of the departure of Professor Nafi Toksoz and his wife, Helena, and Professor Jerry Lettvin and his wife, Maggie, as Faculty Residents from Baker House and Bexley Hall after many years of dedicated service. Since we had not yet replaced Professor Tom Lockwood, who graciously stayed on for another year as Faculty Resident of Random Hall, and with a new house opening in fall 1981, we found ourselves in the position of needing to make four new Faculty Resident appointments. After a lengthy process, involving residents of the houses and Faculty Residents, we are very pleased to announce the following new appointments:

Baker House	Professor and Mrs. Harald A.T. Reiche School of Humanities and Social Science
Bexley Hall	Professor and Mrs. Judah L. Schwartz School of Engineering
"Next House"	Professor and Mrs. William L. Porter School of Architecture and Planning
Random Hall	Professor Irwin A. Pless School of Science

Dining and Residence Programs

This has been the year of change. With the issuance of the Report of the Committee on Campus Dining in October 1979, there has been a great deal of movement towards developing a high-quality residential dining program within the Institute's houses. Chancellor Paul E. Gray's announcement of February 8, 1980, outlined the direction in which the Institute must move in order to provide flexibility for students, reduce the cost of the meal plans, and, most importantly, offer a high-quality dining program that will enhance the residential experience for the Institute's undergraduate population.

In the area of dining, the following decisions have already been made:

1. There will be a combined room and board plan required of residents in McCormick, Baker, MacGregor, East Campus, and Senior House (and Next House in 1981).
2. The Vali-dine computer system will be in operation in the fall. This system will allow for easy transfer between dining facilities and enable students to use their cards for either commons or a la carte purchases.
3. The Dining Advisory Board was appointed by the Chancellor and will provide a forum for campus-wide discussion of the dining program.
4. Arthur D. Little and Co. performed a professional review of the Food Service operation. Specific recommendations were made for improving the quality of the service and cost control.
5. Baker House will remain open until 8 pm to accommodate late diners. A community kitchen is also being planned for Baker.
6. McCormick Hall will reopen its dining room with the concept of providing a focus for women's programming on campus.
7. The menu is being evaluated and provisions made to accommodate vegetarians within the menu structure.
8. Bexley and Random halls will have spaces for women in the fall in order to provide more cooking opportunities for women on campus.
9. Cooking facilities in Burton, New House, Random, and Bexley are being evaluated with recommendations for improvements.
10. Commons committees were active in each house, and student input was elicited when changes involved individual houses.
11. A Program Coordinator, Anita T. Walton, was hired to help coordinate the various phases of the dining program.
12. Kosher Kitchen and the needs of kosher students were addressed. The Planning Office is evaluating the space and will make recommendations for renovating the area.

Complementing the progress in the dining area, a number of residence programs were developed. They include the Institute Forum Lecture Series (in conjunction with the Lecture Series Committee), the Intra-Campus Exchange Program, the Faculty/Guest Meal Program, and the Human Relations Workshops. Other programs are in the planning stage.

Fraternalities and Independent Residences

The Independent Residence System charted new directions this year based upon the experience of the past and the challenges of the future.

The year began with fraternity rush marked by a high number of freshmen waiting to see their dormitory assignment before accepting fraternity bids. The incoming class seemed more self-directed and mature, concerned with their academic performance, and less tolerant of traditional pledge activities. These phenomena, coupled with an unusually high number of freshmen desiring to leave fraternities, caused concern among fraternity leaders and generated extensive discussion. This healthy discourse, focusing on pledging programs and purposes, motivated several houses to study and modify their pledge activities.

A great deal of time and effort was spent in the community relations area, including meetings with the Neighborhood Association of the Back Bay, condominium owners, Boston's District Four police, Boston University's and MIT's Residence staffs, Interfraternity Conference (IFC) officers, and fraternity presidents. Letters were sent out by the fraternities to all of their neighbors in late August explaining what "rush week" consisted of, why there might be some additional activity during that time, and whom to contact at the fraternity or at IFC should the noise become excessive. Overall, a much stronger communication network and level of sensitivity was established, and much of the credit for these efforts goes to Frank Huston, Class of 1982, IFC's Community Relations Chairman, for his leadership in this very important area.

The IFC enjoyed an excellent year under the leadership of Chairman Barbi Hill, Class of 1980, and Vice Chairman Greg Wilson, Class of 1980. Early in the fall term, workshops were organized for house officers allowing for an exchange of information and ideas to happen early in the term.

The Executive Committee of the IFC reorganized itself, emphasizing services to their constituent member Houses rather than focusing on their role as a central governing unit. A committee system was structured, more individual students were incorporated into the organizational network, and many tasks were decentralized or delegated to subgroups. The Executive Committee participated in three day-long workshops designed for them by Stephen Immerman, Business Advisor to Fraternities and Independent Living Groups. The workshops included topics such as establishing priorities, decision making, goal setting, systematic planning, leadership styles, effective meeting strategies, and committee organization.

Under the leadership of Daniel J. Holland, Class of 1958, the Alumni Interfraternity Conference was very active this year pushing forward in a variety of areas. AIFC purposes were clarified and formalized in their newly drafted charter, and new membership was added to the Steering Committee.

The AIFC continued to emphasize the need for long-range planning. A subgroup of the AIFC entitled, "The Task Force on Planning and Priorities for Independent Residences in the Eighties," was formed to address this planning effort, under the leadership of Mr. Immerman.

Information about the organization, administration, and fiscal profile of House alumni corporations was collected using questionnaires and interviews of corporation officers. Strengths and successful programs of individual Houses will be shared for the benefit of the whole system.

Under way are two separate studies, funded by the Institute, addressing physical plant and energy conservation, two of the items listed in the charge to the task force. Before September, each Independent Residence will be inspected by L.M. Evans Inc. detailing short- and long-term physical plant modifications, the expected life of certain physical plant particulars, and the cost of modification in 1980 dollars. Concurrently, American Energy Services Inc. is performing an energy audit on each independent residence providing recommendations for House energy conservation.

Central to the work of the task force is the issue of additional housing for new independent residences. The Institute's extraordinary effort to secure housing for our newest fraternity, Zeta Psi, has been frustrated at every turn. Because of community action and unfavorable zoning regulations, the options for securing property in Boston or Cambridge for the purposes

of housing students are at best limited, if not non-existent. The task force will study the issue and look for current Houses to upgrade their facilities or perhaps even build new homes.

This year's AIFC/IFC Symposium broke with tradition and presented a unified program on management for independent residences. In coordinating the symposium, Greg Wilson, IFC Vice-Chairman, brought together undergraduates, alumni, and staff, producing a most successful program. From the Symposium, a model for House alumni corporations was commissioned and will be shared for House corporations to build from.

At year's end the IFC organized a recognition banquet to thank those who made the year a success.

STEPHEN D. IMMERMAN
 ROBERT M. RANDOLPH
 ROBERT A. SHERWOOD
 ANITA T. WALTON

RESIDENTIAL DISTRIBUTION OF MIT STUDENTS

Fall Term 1979-80

Regular Graduate Students

	<u>Men</u>	<u>Women</u>	<u>Total</u>
<u>MIT HOUSING</u>			
Ashdown	337	57	394
Tang	359	45	404
Graduate Residents (Single)	24	13	37
Total Single Graduates -- On Campus	720 (20.8%)	115 (16.8%)	835 (20.1%)
Eastgate	183	14	197
Westgate	200	9	209
Graduate Residents (Married)	16	5	21
Total Married Graduates -- On Campus	399 (11.5%)	28 (4.0%)	427 (10.3%)
Total Graduates -- On Campus	1,119 (32.3%)	143 (20.9%)	1,262 (30.4%)
<u>OFF CAMPUS</u>	2,343 (67.6%)	541 (79.1%)	2,884 (69.6%)
<u>TOTAL REGULAR GRADUATES</u>	3,462 (100%)	684 (100%)	4,146 (100%)

UNDERGRADUATE RESIDENTIAL DISTRIBUTION

1969-79

Year (Fall Term)	Undergraduate Enrollment ¹	Dorm Occupancy ²		Crowding ⁵	Fraternity Occupancy ³		Off Campus ⁴	
		#	%		#	%	#	%
1969	4074	1866	45.8	--	1250	30.7	958	23.2
1970	4120	1908	46.3	--	1250	30.3	962	23.3
1971	4137	1926	46.6	28	1250	30.2	961	23.2
1972	4183	2009	48.0	78	1250	29.9	924	22.1
1973	4113	1963	47.8	39	1250	30.4	900	21.8
1974	4136	2045	49.4	56	1250	30.2	841	20.3
1975	4433	2272	51.3	55	1252	28.2	909	20.5
1976	4468	2315	51.8	96	1301	29.1	852	19.0
1977	4547	2407	52.9	108	1344	29.6	796	17.5
1978	4594	2431	52.9	134	1296	28.2	867	18.9
1979	4517	2401	53.2	121	1280	28.3	836	18.5

¹Source: Registrar's Reports²Source: DSA Records³1969-74 estimate; 1975 and later, DSA records⁴Subtract (2) and (3) from (1). (Undergraduates in MIT married student housing appear in this number even though they do not live off campus. For 1979, that number is 24).⁵Crowding for 1979 includes 12 vacancies in Bexley Hall.

Department of Athletics

Here are several observations as I reflect upon the role of athletics at MIT: first, there is an awareness of the constant need to keep pace with ever-changing student values in the pursuit of their interests in nonacademic activities, particularly within a university community where first priorities rightly are accorded to a mainstream of academic excellence; and second, is a reminder that MIT students and faculty continue to accord greater value to informal learning experiences outside of the classroom as a desirable, indeed, essential supplement to the traditional opportunities for formal education and personal growth.

The Department of Athletics regards these observations as a vigorous challenge to expand and enrich the opportunities available to all of our students for participation in athletics and recreation. Indeed, the more demanding the academic disciplines, the greater the need for re-creative activity! For a large majority of MIT students, this re-creative activity is developed through a wide range of sports interests which will be reported herein.

Whether the interests of a student are geared to the disciplines of an intercollegiate sport, or to the less formally organized intramural or club sports, or to any one of an array of opportunities for participation in the so-called casual activities available to individuals and to small groups of students -- we believe that our total athletics program promotes a desirable set of values which include:

- a strengthening of favorable qualities of personality, character and self-discipline relevant to the accomplishment of one's career objectives;
- an opportunity and a stimulus for the achievement of excellence, and an identity outside of the academic classroom;
- recreation, in terms of relief of stress, and improved mental and physical well being;
- learning through instruction and execution on the playing fields, much the same as the laboratory relates to the classroom;
- the experiences of "give and take" in competition, striving for individual or team success, learning to rebound from defeat -- at all levels of competition within the program, whether in varsity, intramural or club athletics, or just a friendly game of tennis or squash;
- an opportunity to "team with" as well as "exert leadership" among one's associates -- as one of the most desirable of laboratory experiences which a sound athletics program provides in an educational environment -- for which there is no formal training in the classroom.

To summarize the major objective of the MIT athletics program, I quote from remarks made by President Julius A. Stratton at the October 1959 dedication of the David Flett du Pont Athletic Center: "Society asks more of most people than sheer intellectual ability -- it demands also moral hardiness, self-discipline, a competitive spirit, and other qualities that in more old-fashioned terms we might simply call character."

Twenty-one years later, this quote constitutes an appropriate statement of challenge in a review of events of the past year and a projection of program toward the achievement of desirable goals.

PHYSICAL EDUCATION

One of the outstanding features of the Institute's athletics program is the fact that over 75 percent of our students participate in one or more of the variety of sports and recreational outlets

available on campus. Indeed, the opportunity for students to develop participation interests, regardless of level of skill, has done much to improve the quality of living at MIT, particularly as the residence system has been expanded to accommodate all undergraduates who wish to live on campus.

Underlying the participation phenomenon over the years has been the quality of instruction and variety of courses available in the physical education curriculum. Small classes coupled with professional instruction from members of the coaching staff have ensured a favorable response to the Institute requirement that all incoming undergraduates complete eight points of credit prior to the end of their sophomore year. Whereas, many of our students have been "turned off" by poor secondary school programs, a great majority develop newly acquired skills and move into participation habits of life-long interest.

In the past year, there were 5,861 registrations in 55 courses. This includes 1,620 non-credit registrations by graduate students, staff, and undergraduates seeking instruction beyond the requirement. The emphasis continues to be placed in those activities which may be continued in the years after graduation.

Tables I and II show total registration statistics for the past year, and a five-year summary of registrations including an analysis of the non-credit registrations.

TABLE I

Registration Statistics for 1979-80

Dance	549	Judo	100
Beginning Ballet	106	Basketball Fundamentals	96
Intermediate Ballet	76	Touch Football	77
Modern Dance	37	CPR	73
Partner Dance	245	Karate	72
Tap	49	Rock Climbing	64
Disco	36	Lacrosse	45
Development	485	Yoga	44
Self Designed Fitness	480	T' ai Chi	35
Swimming	450	First Aid	28
Beginning	239	Ultimate Frisbee	28
Intermediate	46	Rugby	27
Advanced Techniques	39	Skin Diving	20
Advanced Life Saving	8	Soccer Officiating	20
Red Cross W. S. I.	35	Bicycling	14
Diving	24	Field Hockey	11
Scuba	59	Basketball Officiating	5
Tennis	404	Independent Activities Period	<u>615</u>
Beginning	240	<u>TOTAL</u>	5,861
Advanced Beginning	20		
Intermediate	144		
Sailing	369		
Pistol	270		
Fencing	213		
Rifle	191		
Archery	173		
Volleyball	169		
Squash	163		
Sculling	120		
Badminton	117		
Softball	115		
Gymnastics	114		
Gymnastics	37		
Trampoline & Gym.	77		
Golf	105		
Beginning	88		
Intermediate	17		

TABLE II

Five-Year Summary -- Analysis, Physical Education Registration

	<u>79-80</u>	<u>78-79</u>	<u>77-78</u>	<u>76-77</u>	<u>75-76</u>
(a) Total Registrations	5,861	5,939	6,232	6,462	6,354
Change Over Previous Year	-78	-293	-150	+108	-528
Percent Change Over Previous Year	-1.3%	-4.7%	-2.5%	+1.7%	-7.6%
<hr/>					
(b) Non-Credit Registrations	1,620	1,741	1,195	2,492	2,053
Change Over Previous Year	-121	+546	-1,297	+439	-614
Percent Change Over Previous Year	-6.1%	+45%	-52%	+21%	-23%
<hr/>					
(c) Analysis of Non-Credit Registrations					
<u>Students</u>					
1st Year	59	77	1	65	58
2nd Year	186	190	24	308	313
3rd Year	268	186	52	413	282
4th Year	276	260	50	336	388
Graduates	578	739	770	905	734
Staff	253	289	298	465	279
	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>
	1,620	1,741	1,195	2,492	2,054
<hr/>					
(d) Total Registrations Less Non-Credit Registrations					
Total Registrations	5,861	5,939	6,232	6,462	6,354
Non-Credit Registrations	1,620	1,741	1,195	2,492	2,053
	<hr/>	<hr/>	<hr/>	<hr/>	<hr/>
	4,241	4,198	5,037	3,970	4,301

INTERCOLLEGIATE ATHLETICS

The past year has been marked by characteristics and events quite typical of an intercollegiate program at an institution where varsity and sub-varsity athletics are considered to be an integral part of the total educational experience. These characteristics include: large numbers of undergraduate men and women deeply committed to their respective sports at a highly disciplined level; practicing, conditioning, and competing regularly in efforts to achieve excellence; self-motivated, engendering self-respect, pride, identity, and cohesiveness in group effort, generally in the absence of major spectator interest. This is amateur athletics at its best!

Although MIT teams and individual student-athletes are not associated regularly with achievement of national acclaim, it is interesting to note that two recent graduates were members of the United States Olympic Team selected for the 1980 Games scheduled for Moscow: John Everett, Class of 1977, in the eight-oared shell for rowing, and Mark Smith, Class of 1978, on the fencing team. Other regional and national honors will be discussed subsequently under separate headings for the men's and women's programs.

Interesting statistics indicate that close to 900 undergraduate men and women were active in 32 sports and participated in 627 events at home or at colleges and universities within the New England and Eastern regional conferences. This includes regional and/or national championship competitions for which MIT teams or individuals qualified this past year in 28 of the 32 sports.

There are some duplications among the 900 undergraduates in the intercollegiate program, i.e., those students who participate in separate sports in the fall and spring. However, approximately 20 percent of the regularly enrolled undergraduate men and women annually make the in-depth commitment to intercollegiate athletics at MIT. Perhaps a more significant statistic is the fact that 628 varsity, sub-varsity, and frosh awards were earned this past year.

Intercollegiate Letter Awards for 1979-80

<u>Undergraduate Men</u>		<u>Undergraduate Women</u>
251	Varsity Letters	98
163	Sub-Varsity	64
40	Frosh Numerals	12
<u>454</u>		<u>174</u>

Men's Intercollegiate Honors

- The fencing team completed the best season in the history of the sport at MIT: a second place tie with Pennsylvania in the NCAA open national team championships (three events); and winner of the Intercollegiate Fencing Association championship in the épée competition led by Captain George Gonzalez-Rivas, Class of 1980, and Eric DeBeus. Coach Eric Sollee was named College Fencing Coach of the Year by the National Fencing Coaches' Association.
- The basketball team compiled its best won-loss record since 1968 (13-9). Co-Captain Ray Nagem, Class of 1980, was named to the 1980 Academic All-America Team in the College Division; and Mark Branch, Class of 1983, was selected on the All East Frosh Team by *Eastern Basketball* magazine. Coach Francis O'Brien was selected New England Division III Coach of the Year by the National Basketball Coaches' Association.
- Golfers Doug Parigian, Class of 1980, and Ned Emerson, Class of 1981, qualified and competed in the NCAA Division III championships in leading the golf team to an 18-2 team match record in their combined fall and spring competitions. Mr. Parigian was named to the NCAA Division III All America Golf Squad following the tournament.
- The swimming team enjoyed its fourth consecutive winning season (6-3). Freshman John Schmitz won All American honors in three events at the NCAA Division III championships. Sophomore David Erickson was also named to the All America Division III team in the same championships.

- The indoor and outdoor track teams had a combined dual meet record of 8 wins and 5 defeats. Freshman Paul Neves set all-time MIT records in four middle distance running events. He was named to the Greater Boston Collegiate Athletic Conference all-star team to compete against the Metropolitan New York Athletic Conference. He also qualified for the NCAA Division III Championships along with Martin Taylor, Class of 1983, Colin Kerwin, Class of 1982, and Dave Kieda, Class of 1982.
- The rifle team finished its sixth consecutive winning season with an impressive 22-3 record in capturing the New England College Rifle League Championships.
- The lightweight varsity oarsmen won the Biglin Cup Regatta in competition with Harvard and Dartmouth, and went on to finish fifth in the lightweight championships of the Eastern Association of Rowing Colleges.

Women's Intercollegiate Honors

- The varsity eight crew was the fourth fastest crew in the Eastern Sprints, and because of this commendable performance, they were invited to participate in the first National Collegiate Regatta in Oak Ridge, Tennessee. At the Nationals, this crew won the petite finals. Sara Henderson, Class of 1983, rowing with the Eastern Development Camp at the National Women's Rowing Association (NRWA) Championships, was selected as a member of the US Junior National Women's Crew.
- Karen Haug, Class of 1982, won the #1 singles championship in the Massachusetts Association of Intercollegiate Athletics for Women (MAIAW) Division III Championships. The tennis team was selected to participate in the EIAIW Division III Championships at Trenton State College.
- Karen Klinecicz, Class of 1982, joined five MIT swimming teammates in the AIAW Division III National Championships. At the Nationals, Karen made All-American in four individual events. Karen was the New England 200-yard butterfly champion.

Other Noteworthy Events

- At the February meeting of the Athletics Board a resolution was adopted unanimously to submit a resolution to then Chancellor Paul Gray in response to a request from the NCAA to document MIT's policy with regard to the governance of women's intercollegiate athletics. The resolution reaffirmed MIT's support of the Association for Intercollegiate Athletics for Women (AIAW) as the appropriate governing body for women's intercollegiate athletics.
- Harriett Pearce, assistant trainer, was selected as a member of the Sports Medicine Group for the 1980 Winter Olympic Games at Lake Placid, New York.
- Jane Betts served as the president of MAIAW and as the treasurer of EIAIW during the 1979-80 year. She directed the 1980 New England Men's Gymnastics Championships held at MIT in March. Jane has been appointed chair of the AIAW interim sports committee for crew, a committee that will develop a national AIAW crew championship. In June, Jane spoke at the NACDA Convention Division III Breakout Session.

INTRAMURAL ATHLETICS

Intramural athletics continue to draw the largest participation of any single division within the scope of the total MIT athletics program -- regularly attracting more than two-thirds of our undergraduate men and women and a significant number of graduate students in one or more of the 27 sports currently offered.

The spirit and cohesiveness of natural groupings developed among the fraternities and Institute residences accounts for the popularity of intramural athletics. Further, the vast number of

teams organized in the traditionally popular sports is enhanced by a system of classification developed over the years by the student-organized and student-governed Intramural Council. In basketball, for example, the 149 teams entered this past year were classified (often by self-determination) into "A," "B," and "C" leagues in order to attract and provide good competition at all levels of skill.

The most significant factor in the success of intramural athletics is the quality of student leadership responsible for the day-to-day planning and implementation of the program through the Intramural Council. The Council is composed of representatives of living groups, recognized organizations, and departments throughout the Institute. Its Executive Committee meets weekly with the Staff Coordinator for Intramural Athletics to ensure the smooth flow of schedules, maximize use of facilities, sponsor officials' training programs, rule on protests and eligibility requirements, and to guide evaluation and innovation to meet changing interests among students.

This past year there were 1,195 teams organized in 27 sports with an estimated 11,300 students participating, including duplications reflected in the statistics by those students who participate in more than one sport.

Intramural Participation Statistics 1979-80

<u>Sport</u>	<u>Number of Teams</u>	<u>Approx. No. of Participants</u>
Badminton	44	220
Basketball	149	1,192
Bowling	120	360
Chess	12	72
Cross Country	22	152*
Cycling	4	67*
Fencing	12	64*
Football	89	1,335
Frisbee	28	280
Hockey	29	348
Octathlon	22	264
Pool	25	225
Rifle	32	139*
Rugby	8	72
Sailing	10	40
Soccer	80	1,460
Softball	155	2,170
Squash	42	210
Swimming	14	108*
Table Tennis	78	546
Tennis	--	128
Track (Indoor)	--	--
Track (Outdoor)	16	141*
Volleyball	146	1,168
Water Polo	39	390
Weightlifting	8	68*
Wrestling	11	81*
	<u>1,195</u>	<u>11,300</u>

* Tournaments or one weekend events. All others are round-robin leagues.

CLUB ATHLETICS

A "club" team, as distinguished from a university-sponsored intercollegiate team, is self-operated and financed within a special interest group, generally, in one of the sports less popularly supported among the colleges and universities of this country. Devoid of the traditional and often "sticky" eligibility rules governing the intercollegiate competition in varsity athletics, club teams are particularly popular among graduate students at MIT and others who are unable to make regular commitments to more highly organized inter-college competition.

The recent years of financial crisis have restricted the addition of new sports, and indeed, have resulted in dropping some of the traditionally budgeted sports at many institutions. Some of these sports regroup, after establishing a funding base, and come back as club teams using the institution's name and facilities where possible. In a few instances, new sports have been added via the club route, as was the case with football at MIT.

As attractive as the club route may appear, in terms of relief of demands on the university's resources, the Department must continue to guard against the potentially inherent risks of poor coaching, inadequate sports medicine services, unsafe equipment, poor practice and game conditions, and other factors. This is especially so in sports where certain essential services and requirements cannot be side-stepped, i.e., in the case of Club Football at MIT, the Athletics Board approved sponsoring the sport with the following stipulations:

- Club Football must be supervised by the Department of Athletics;
- All students must have extended insurance coverage acceptable to the Medical Department;
- The cost of Club Football shall not impact on any present student activity programs, and should be borne within budgets controlled, at that time, by the Office of the Dean for Student Affairs; and
- The Medical Department will provide the quality of medical service which it deems necessary, and the costs are to be considered part of the total expense of Club Football.

In summary, the Department of Athletics encourages and supports club sports within the practical limits of available budget in the belief that "clubs" bring together undergraduates, graduates, and faculty in athletics which foster desirable relationships outside the classroom.

Club Rosters for 1979-80

Archery	10	Rugby, Men	25
Badminton	16	Rugby, Women	18
Cheerleading	10	Scuba	28
Crew, Graduate*	--	Soccer, Graduate	18
Cricket	20	Square Dance	22
Cycling*	--	Squash, MSRA	18
Fencing	22	Squash, Women*	--
Figure Skating	--	Table Tennis	10
Football	45	Tae Kwon-Do	20
Folk Dance	35	Volleyball, Men	12
Hockey	22	Water Polo, Women	12
Judo	18	Weightlifting*	--
Karate, Shotokan	20	White Water	20
Rifle and Pistol	45	* Inactive 1979-80	

RECREATION FOR STUDENTS AND THE MIT COMMUNITY

The recreational interests of students and members of the MIT community are a major concern of the Department, particularly the interests of those students who choose not to participate in organized intramural, club, or intercollegiate athletics. Indeed, one of the major objectives within

the MIT athletic program is to introduce students to sports interests which may be developed into lifelong recreational outlets. Toward the attainment of this goal the Department offers top-quality instruction in a variety of courses in physical education curriculum, as well as regularly scheduled shore schools at the sailing pavilion, summer tennis classes at the du Pont courts, and so on.

The most visible evidence of the success of this broad objective, coupled with a philosophy of encouraging sports participation for all students, is the degree to which the MIT athletics facilities are utilized by the so-called "casual" participant -- almost around the clock!

The annual sale of Athletic Cards best reflects the broad base of recreational and fitness interests within the MIT community. This past year, a total of 9,288 cards were purchased within the student-staff-alumni community. This statistic includes 6,574 student cards, indicating that 77 percent of 8,475 registered full-time students, undergraduate and graduate, were active in some phase of the athletic program.

Athletic Card Sales for 1979-80

Students		6,574
Faculty	332	
Staff/Employee	1,664	
Family Cards	<u>379</u>	
		2,375
Alumni		<u>367</u>
		9,316
Sailing Cards:		
Students	846	
Faculty/Staff	201	
Alumni	82	
Specials	279	
Physical Education	<u>376</u>	
		1,784

CAMBRIDGE AND GREATER BOSTON COMMUNITY RELATIONS

The Department continues to work in close liaison with the office of Walter Milne, Special Assistant to the President for Urban Affairs, in extending the use of our athletic facilities to community interests at times not in conflict with students' interests. Although we are especially sensitive to the desirability of sponsoring programs promoting interaction between our students and young people from the surrounding communities, we have been pleased to host a number of large and appropriate indoor events in the du Pont Gymnasium and Rockwell Cage, generally, during the spring, summer, and fall seasons when there is minimum conflict with regularly scheduled athletic commitments. The annual Massachusetts State Science Fair and the Cambridge Mayor's Spring Reception and Dance are typical of the latter.

The NCAA Volunteers for Youth is an example of a successful endeavor in bringing MIT students in the Cambridge community in a one-on-one program of benefits to both groups. Also, a major block of time at Alumni Pool on Saturday mornings is committed annually to a Learn-to-Swim Program conducted by members of Alpha Phi Omega for the Boy Scouts of Cambridge. The MIT Child Care Center conducts a Toddlers' Swim Program, and Women's Enterprises of Boston regularly share open swimming time in connection with their New Horizons' Program for girls ages 12-14. These are just a few of many desirable relationships with our neighbors. Other community involvements include the use of the athletic fields and indoor facilities during off-peak hours by the Cambridge Rindge and Latin School, currently in a major reconstruction of their physical plant. Also, the Cambridge Sports Union and the Roxbury Track Club are using the new outdoor track facilities compatible with our MIT schedules.

The Department's desire to maintain an "open door" policy in the accommodation of community interests, however, has not been without serious security problems. Following an extensive two-year review of the problems encountered by Campus Patrol and Physical Plant, a security system will be used in the new Ice Rink-Field House-Events Center which will help to eliminate the problems of vandalism and property loss while maintaining a desirable policy of scheduled and controlled guest use of our facilities.

MAJOR ATHLETIC AWARDS FOR 1979-80

The Class of 1948 Award to the Senior Athlete of the Year was presented to George Gonzalez-Rivas, Class of 1980. The Admiral Edward L. Cochrane Award to the senior who has best combined the qualities of leadership, humility, and scholarship in intercollegiate athletics was awarded to Timothy J. McManus, Class of 1980. The Betsy Schumacker Award for excellence in athletic competition by a woman student was won by Karen M. Klincewicz, Class of 1982.

The Straight T Award for national or regional recognition in intercollegiate athletics at MIT was presented to the following: Eric Debus, Class of 1982, George Gonzalez-Rivas, Class of 1980, Paul D. Hartung, Class of 1980, Karen E. Haug, Karen M. Klincewicz, Class of 1982, Raymond J. Nagem, Class of 1980, Geoffrey G. Pingree, Class of 1981, John M. Rodrigues, Class of 1980, John S. Schmitz, Class of 1982, Robert V. White and Fred J. Wysocki, Class of 1980.

The Burton R. Anderson, Jr., Award to the Manager of the Year was presented to Cammy R. Abernathy, Class of 1980. The Varsity Club Award to the Frosh Athlete of the Year was won by Paul S. Neves and John S. Schmitz, both of the Class of 1983. The Harold J. Pettegrove Award for outstanding contributions to intramural athletics was awarded to Steven J. Pettinato, Class of 1980.

STAFF CHANGES

Retired:

Ross H. Smith, Professor, Director of Athletics.

Resigned:

Wilfred R. Chassey, Associate Professor Physical Education and Coach of Wrestling, to accept appointment as Director of Athletics at Hampden-Sydney College.

Bruce R. Keeshin, Instructor Physical Education and Coach of Men's Gymnastics, to enter business.

Robert G. McQuaid, Assistant Trainer, to pursue graduate study.

Christopher P. Lane, Coach of Cross Country and Assistant Coach of Track, part-time.

John B. Miller, Coach of Women's Rowing, part-time.

Wayne M. Pecknold, Coach of Ice Hockey, part-time.

Appointed:

Royce N. Flippen, Jr., Professor, Director of Athletics.

Clifton L. West, Assistant Professor Physical Education, Coach of Cross Country, and Assistant Coach of Track.

F. Timothy Walsh, Assistant Professor of Physical Education, Coach of Wrestling, Assistant Coach of Club Football and Lacrosse.

Joseph G. Quinn, Instructor Physical Education and Coach of Ice Hockey.

Douglas M. Clark, Instructor Physical Education and Coach of Women's Rowing.

Robert B. Horwitz, Coach of Men's Gymnastics, part-time.

On leave:

Manuel Weiss, Assistant Professor Physical Education.

ROSS H. SMITH

Office of Admissions

This coming September will see a freshman class number just over 1,075 students. Of those who were offered admission, the percentage who plan to register increased again this year. The faculty, whose significant support is critical to the task, and the staff who reviewed the applications, found the group to be one of the most diverse, energetic, and talented of applicants seen in several years. As in years past, they come from across the land and over the seas, 48 states and 28 countries. Minority enrollment will be about the same as in 1979, but the number of women (24 percent) is the highest ever.

As the anticipated decline in high school seniors during the 1980s impacts on the universities and colleges, the competition for students, particularly quality students, will change the nature of the great sorting process that occurs each spring. It is important at all times in the admissions process that the interests of the applicant prevail and this will be a much more difficult standard to achieve in the coming years. To continue to attract top quality students, we at the Institute must provide first-class, diverse educational opportunities and articulate clearly the potential impact of a science-based education for a young person. Women and minorities must be encouraged to seek out the opportunities at MIT in ever increasing numbers -- no small challenge for the Admissions Office.

This past year a decision was made to develop a Data Management System for the Admissions Office and the Educational Council Office. The increased ability to respond to applicants' requests and with timely availability of information on our applicant pool will provide the office with the needed capacity to accomplish our mission in the forthcoming intensified competition for students.

Unprecedented consumer activism in the state legislatures and the Congress, with the Scholastic Aptitude Test the explicit target, has taken place over the last year. New York, with its "Truth in Testing" Law on the books, is the location of the great experiment. The real target of this movement is selective admissions. Test scores have provided MIT with useful information in the identification of talented students, and are useful indices when used in conjunction with other personal and academic indicators. The nationwide discussion of testing and the admissions process continues. We shall need to take an active role in the coming months.

Transfer applications continued the tradition of adding to the undergraduate student body able young men and women who began their college educations elsewhere. Approximately 1,200 inquiries were received, yielding about 400 final applications. Admissions of between 120 and 150 candidates will lead to registration of 100 to 125 students with advanced standing -- either second or third year. Many of the students admitted via transfer application are non-traditional, in MIT's context, having interrupted educations for military service or employment. As a result, they add an experiential dimension to the campus community, bringing to their studies and extracurricular involvement a dedication and depth of particular merit.

In a move discussed in last year's report, the international student team will move to new quarters in Building 5 and join other counseling services reporting to Shirley McBay, the Dean for Student Affairs. The Admissions Office will continue to exercise the responsibility for the admission of international students. Gene Chamberlain, who joined this office in 1954, will be missed, but we are happy he will just be around the corner.

Joe Edwards, who has done an outstanding job as Director of the MIT Educational Council, leaves to take a new position in Milwaukee. The growth and strengthening of the Council, in terms of numbers (particularly women and minorities) as well as the innovations and improved publications for which he has been directly responsible, cannot be overestimated. His energy and his incisive mind will be missed as we face the challenges ahead.

PETER H. RICHARDSON

ADMISSIONS TRENDS 1974-80

	<u>1974</u>	<u>1975</u>	<u>1976</u>	<u>1977</u>	<u>1978</u>	<u>1979</u>	<u>1980</u>
<u>Entrants from Secondary Schools</u>							
Preliminary applications	7,651	8,166	8,104	7,853	9,320	10,274	11,223
Final applications	4,584	4,726	5,194	4,838	4,870	5,368	5,677
Admissions Offered	1,936	2,106	2,277	1,939	1,865	1,813	1,809
Actual registrations	1,036	1,154	1,044	1,073	1,059	1,059	1,081
Registrations as percent of admissions	53.5%	54.7%	47%	55.3%	56.7%	58.4%	59.7%
Number of secondary schools represented	808	918	866	859	877	893	894
Percent of students from 9 north-eastern states	52%	50.8%	48%	52%	50.6%	49%	47.8%
<u>College Transfers</u>							
Total applications	791	879	941	1,079	1,074	1,143	1,131
Applications completed	338	499	536	591	535	486	471
Admissions offered	166	200	203	175	172	152	167
Actual registrations	123	155	162	141	123	124	119
Registrations as percent of admissions	74%	77.5%	80%	81%	72%	82%	71%
<u>Graduate Students</u>							
Total applications	6,213	6,447	7,511	7,740	7,454	7,849	7,832
Admissions offered	2,060	2,119	2,676	2,644	2,724	2,636	2,380
Actual Registrations	1,058	1,015	1,441	1,369	1,461	1,362	1,212
Registrations as percent of admissions	51%	48%	54%	52%	54%	52%	51%

Office of Student Financial Aid

The financial aid year was one of paradoxes. Massive increases in Federal grant programs set against disappointingly small increases in endowment funds and gifts from private sources. The largest jump in tuition in the Institute's history, leading to a substantial increase in average financial need, set against a drop in the number of students with need. A Federal College Work-Study Program, close to \$2 million, and a substantial increase in wage rate for student employees, set against a significant drop in the number of students working on campus. A windfall of low-interest Federal National Direct Student Loan funds, bringing the lending level in that program to an all-time high, set against drastic reductions in the same program forecast for next year. And the largest ever aggregate need to be funded by the aid program set against a reduction by almost half in the allocation of unrestricted Institute funds necessary to augment the scholarship program.

Grant Programs

The passage by Congress of the Middle Income Student Assistance Act (MISAA) opened the Basic Grants Program to hundreds more MIT students than in the previous year, increasing the total awards in that program from about \$400,000 to more than \$1 million. The Federal Supplemental Grants Program increased by 54 percent to \$1.2 million. The three ROTC programs provided more than \$1 million in scholarships to needy students. All told, these three Federal grant programs accounted for 46 percent of all scholarship aid received in 1979-80 by needy students. In contrast, the scholarship endowment was increased by \$1,119,000 -- enough to add only about \$56,000 per year to the scholarship award program.

Loan Programs

The most widely known feature of the MISAA is the resultant annual availability, to nearly every student, of a \$2,500 low-interest bank loan (partially Federally subsidized) for undergraduates and \$5,000 for graduate students. The removal of red tape from this program, coupled with financial conditions that favor banks making these Federally guaranteed loans, served to increase the use of this program by all MIT students from \$3,360,000 in 1978-79 to \$6,005,584 in 1979-80. Most undergraduates have used this loan program to reduce the proportion of their expenses that must be paid by their parents, but many have applied it instead to the "self-help" component of their financial aid package to preclude the necessity of working during the academic year.

Student Employment and the College Work-Study Program

The wide availability of guaranteed loans has evidently had the effect of reducing the total on-campus earnings of needy undergraduate students. The number of needy students working decreased as well. Although this phenomenon has its good connotations -- students are evidently enjoying more flexibility in the use of their time -- the corollary trend to increasing indebtedness is certainly not a particularly encouraging sign.

Participation by graduate students in the College Work-Study Program held steady, as research assistants joined the program, offsetting a continued downward trend in teaching assistant participation. The continuing low level of graduate participation, in spite of stepped-up efforts on our part to encourage voluntary response, has prompted the administration to incorporate into the registration process a requirement for the documentation necessary to establish eligibility in the College Work-Study Program.

Staff Notes

During the year Rita Nethersole resigned her staff appointment to begin new responsibilities with the Massachusetts Pre-engineering Program for Minority Students in Boston, and Nelson Armstrong left the SFAO to join the Admissions Office as Associate Director. Lucy Van der Wiel (A.B. Wellesley College), assumed the responsibilities of Assistant Director of Financial Aid and Director of Student Employment.

JACK H. FRAILEY

Career Planning and Placement Office

The past year was one of continuing growth in the number of students using the Office. We estimate that 1,200 students came to talk with the staff about their career plans or to meet with company and graduate school representatives. An invitation to United States students in science and engineering to submit resumes for a resume book, which the Office distributes to interested companies, elicited 747 resumes. Student interviews with visiting recruiters totaled 8,718, an all-time record. Four hundred and four companies and government agencies made one or more visits, some coming three or four times during the year. Companies have been coming to the Office to meet interested students since World War II, if not longer.

Employer demand was strong in almost all areas of engineering and the physical sciences. It was also a good year for students in other departments who had a background in computers or economics. Management consulting firms expressed an interest in hiring analytically oriented students as research associates to work with their consulting staff for two years or so before going on to graduate school for a professional degree. Some leading banks and investment firms, and some Wall Street law firms, presented a similar opportunity. A prominent Boston consulting firm which is noted for the high salaries it pays M.B.A.s offered \$23,000 to new bachelors joining its staff as research associates. Another Boston firm, equally prominent, explored the idea of hiring equally qualified young holders of the bachelor's degree in place of M.B.A.s. The MIT curriculum, with its stress on problem solving, its emphasis on research, and its professionalism, is splendid preparation for such opportunities and the firms appear to realize it. Their interest in bachelor's degree graduates is a new development and it may not be more than a passing phase, but if it continues or expands it represents an interesting new option for our students to consider.

Salary offers in science and engineering rose 9 to 12 percent at the bachelor's level, not quite keeping pace with inflation. Salaries at the graduate level, which in recent years have risen more slowly than bachelors' salaries, this year rose equally fast or faster. Offers to master's degree candidates in electrical engineering went up 15 percent and offers to masters in materials sciences jumped 16 percent. Offers to Ph.D. candidates rose 9 percent in electrical engineering and 11 percent in chemistry. Industrial salaries were highest for Ph.D.s in electrical engineering, hitting a median of \$31,380; next was chemical engineering, at \$29,280, followed by physics and materials science at \$28,800. The total number of US students completing doctorates in engineering has declined 46 percent since 1970. Many new Ph.D.s in engineering are clearly more attracted by opportunities in industry than by an academic career. A number of engineering department heads around the country have talked of the difficulty of finding faculty. One, in fact, joined the throng of company representatives coming to the Office to find candidates for his department.

The strong demand in engineering and the physical sciences, which continued unabated at the end of the year in spite of the economic recession, is traceable to a number of factors. One is the continuing revolution in computer technology, which has made it possible to use computing devices in more and more applications. Another is the challenge thrown down to technology by the rising price of energy. Leaving aside government programs to encourage the development of new energy technologies, firms have been under pressure from the marketplace to review every energy use. The new synthetic fuels program, added to other government programs, ensures that this concern with energy technology will continue. A third factor is the nation's renewed concern with defense. A fourth factor, surely, is the challenge from foreign technologies. Firms which were complacent about their technology a decade ago are finding that they can no longer rest on their oars. This point was made by more than one firm visited during the year. The president of a farm-machinery company talked of matching Japanese productivity and quality control. Another company visited, which may be thinking of building industrial robots for use in their own factories, was testing robots built elsewhere around the world. The robots in the testing laboratory were made by five manufacturers, of whom one was Japanese, one Swedish, and one Norwegian. Only two were American. Foreign competition is even challenging methods of recruiting. Representatives of a Japanese publishing house visited the Office during the year to explore the feasibility of a new recruiting publication to be distributed in this country. The challenge of foreign technology, as

well as the other factors mentioned, can be expected to stimulate the demand for scientists and engineers for many years to come.

Life scientists have not been beneficiaries of the same level of industrial demand as physical scientists and engineers, but there is a possibility that this is now changing. One hopes so, because there are more highly trained young biologists in the market at all degree levels than there are jobs for them in the universities or government. One field in which demand is already strong is toxicology. Another is fermentation. What may radically alter the picture, however, are developments in genetic engineering. So far we have not seen companies' interest in the field expressed in their campus recruiting. Nor has it stimulated perceptibly the overall demand for life scientists. Pharmaceutical firms visiting the office continue to be more interested in talking with chemical engineers, computer people, and chemists than with life scientists. We are endeavoring to remind employers that when they want life scientists -- whether they are after molecular geneticists, crystallographers, biochemists, microbiologists, immunologists, toxicologists, or nutritionists -- MIT is a preeminent place to come.

There was much discussion during the year regarding the connections between the various counseling offices at the Institute. Career Planning and Placement is one of a number of offices which in various ways are concerned with students' job and career plans. They include the Undergraduate Academic Support Office in the Office of the Dean for Student Affairs, the Preprofessional Advising and Student Assistance Services in the Dean's Office, the International Students' Office, and the Student Employment Office. We have cooperated with all of these offices in programs of one sort or another during the year. Among the joint ventures were an undergraduate career seminar (held during fall term), a career day for freshmen ("Trailblazing" -- held for the second time this year), an annual career conference for black students, and a new effort sponsored by the Alumni Association to help find summer jobs for freshmen.

More than half the students using the Office are graduate students and the Office has strong ties with the academic departments. Some departments have their own placement services for their graduate students, but the Office's collection of employer literature is unmatched at the Institute and students from all departments come to use it. For example, a collection of brochures which architectural alumni have helped us to gather on employers of architects also has proved to be an excellent resource for planners and civil engineers.

We have two guiding principles. One is to provide as much relevant information as possible to help students and alumni identify and choose among the options open to them. The other is to keep our doors wide open, inviting anyone to sit down and talk, however tentative his or her present thinking. We have a reciprocal program with our colleagues at Harvard and Wellesley, welcoming their students and referring our students to them. We are also happy to talk with others who cannot find the help they need elsewhere. For example, we have recently assisted a number of Russian emigré scientists and engineers. Outsiders who do not know what they can expect from us provide a nice test of our services.

ROBERT K. WEATHERALL

Personnel Office

The reports which follow review the highlights of the past year in the various offices that comprise the MIT Personnel Office. They report a year of achievement and consolidation.

The offices continued to strive toward expanded service to the community to make MIT a rewarding and supportive work environment. As in recent years, the past year has been one of continued pressure on administrative budgets. Inflationary pressure, the need for interpretation and implementation of Federal regulations, rising expectation for service, and other factors impose heavy demands on the various offices. These demands require creative leadership in a time of restrictive budgets and staffing. I would like to express my admiration and appreciation to the staffs of these offices for the skill and dedication in the conduct of the Institute's business.

The year was marked by the departure in March of John M. Wynne, Vice President for Administration and Personnel, to devote himself to family business matters. Mr. Wynne had provided creative leadership for the personnel function of the Institute for over eight years.

A number of other changes in staffing also occurred during the year. George N. Petievich joined the office in the new position of Project Manager, with the responsibility for the development of the computerized system for personnel information. Robert J. Nelson left the office for a business opportunity elsewhere. Other changes are listed in the section reports following.

A major restructuring was undertaken in our Personnel Development efforts in response to budget pressures. These pressures led to a consolidation of the Office of Personnel Development with the other divisions of the Personnel Office. It is hoped that through this consolidation we will remain able to continue to provide for the training and development needs of the community in future years. During the next year I will be attending all of the existing personnel development courses in an attempt to evaluate and reformulate our efforts in this important area.

JAMES J. CULLITON

BENEFITS ADMINISTRATION

The Benefits Office continued its efforts to provide more effective communication of benefit plans to the Institute community.

One of the Office priorities for the year was a review of the effectiveness of our communications techniques. As a result of this review, we commissioned the development of a new Audio-Visual Program that, for the first time, would encompass all of the major benefit plans. This recently completed program is expressly designed for presentation at departmental meetings by the Benefits Office staff. To date, this program has been effective as a communications tool, by initially stimulating individual thought and subsequently a dialogue with us on a variety of personal planning matters.

We also have been actively involved in assuring that our plans adhere to the rapidly changing Federal regulations for benefit plans. The mandate on benefit plans of the 1978 Amendment to the Age Discrimination in Employment Act, for employees who choose not to retire at the Institute's normal retirement date, is still unclear in some areas. However, we have made certain changes when definitive regulations have been issued. One such change in our medical program last October assured the age 65 and over employee the same level of benefits enjoyed prior to attaining age 65. This liberalization is currently in effect in each of our medical plans.

On January 1, we welcomed the Harvard Community Health Plan as our third medical option, and on June 16 the Benefits Office assumed responsibility for the administration of the Tuition Assistance Plan.

RICHARD P. MARVEL

OFFICE OF CHILD CARE

The Child Care Office has continued in its efforts to meet the ever-increasing demand for child care services for young children.

A new program of workshops and discussion groups for working parents has been started this year, in conjunction with the Health Education and Information Office and the Social Work Service of the Medical Department. One such discussion group has been developed around the problems that mothers of young infants encounter when returning to work. This group was started in response to the growing number of working mothers who have come to us with a variety of concerns centered around working and parenting. It is hoped that the groups will become a regular part of the service that we offer.

During this past year, a total of 321 children used the MIT-related child care programs, an increase of 16.3 percent over the previous year. Approximately 250 other families received assistance in finding programs located elsewhere.

Most of the families (44 percent) who used the services had student affiliations. Only one exempt employee and no service employees had children enrolled in services at the Institute. Thirteen percent of the families had faculty affiliations, 19 percent had other academic appointments, 10 percent had administrative staff affiliations, 13 percent research staff, and 10 percent had support staff affiliations. Three percent were from Draper and two percent had Lincoln affiliations.

Family Day Care (FDC)

Family Day Care, a home-based program designed primarily for infants and toddlers, accommodated 180 children during the past year. This represents an increase of 36 percent over last year. Nearly half of the children were under 12 months of age, while 10 percent were eight weeks old or younger. There was a three percent increase in the number of children over two years and nine months (pre-school aged), an indication that our center-based programs are not sufficiently large enough to meet the demand.

To truly reflect family day care activity, one must note that in addition to the numbers cited above, 63 children were transferred from one home to another. The majority of these transfers were necessitated by changes in the providers' situations. Either they themselves became pregnant and inactive temporarily or they left MIT and moved elsewhere.

There is no question that family day care, besides being an important source of child care, is also an important source of income for those who become licensed providers. The number of providers more than doubled this past year. Of the 92 people who provided care, 55 were newly licensed by the Commonwealth of Massachusetts. As in previous years, almost all FDC providers were student wives.

Technology Children's Center, Inc. (TCC)

TCC, a private, non-profit corporation, provides center-based, pre-school programs for children who are at least two years and nine months old. There are currently three such programs operating on campus which provide full-day, year-round care; part-day care during the academic year and six weeks during the summer; and full-day kindergarten. A total of 135 children were enrolled in TCC during this last year.

Personnel Office

Based on current applications and projected enrollment, we will not be able to accommodate all those who might have wanted to use TCC programs in this coming year.

MARGARET SAND

OFFICE OF LABOR RELATIONS

The Office successfully concluded a new three-year Agreement with the MIT Police Association (the representatives of the Campus Patrol Officers) which provides for an eight percent wage increase for the first year and seven percent for the two remaining years of the Agreement. In addition, a new administrative system for filling overtime assignments was agreed upon. After a prolonged evaluation of the sharp rise in the cost of living during the 1979-80 fiscal year and its impact on employees and their families, the Administration proposed to all unions that the effective date of the June 30, 1980, general wage adjustment be advanced to March 17, 1980. All bargaining units accepted the Institute's offer.

The Service Employees International Union, Local #254, in August 1979, filed a petition with the National Labor Relations Board (the Board) asking that the Institute be ordered to include in the campus bargaining unit certain Service Staff employees of Endicott House, Talbot House, and the Clinical Research Center, along with a number of Support Staff personnel performing console operator functions in the Physical Plant Department and the Telecommunication Office. A hearing was held and the Board dismissed the petition on the grounds that the Union had failed to submit sufficient evidence to support its position. Closely following this award, in December, the Union filed two new petitions with the Board stating that they represented a majority of employees in the Clinical Research Center and the Physical Plant Board Control group. After five and one-half days of hearings before the Board, the Institute and the Union reached an agreement that the Union would drop both petitions, the Institute would place a certain position within the bargaining unit, and the parties would arbitrate the issue of a group of Service Staff employees at the Endicott House being covered by the present Agreement for the campus. The arbitration was held with the Institute's position that the employees in question were properly outside of the scope of the campus bargaining unit being upheld by the arbitrator.

The administration of the eight union Agreements with the various unions representing employees on campus, at the Lincoln Laboratory, and the Millstone Hill complex have proceeded normally during the fiscal year. The number of grievances from all unions are slightly below normal, but the arbitrations continue at a steady rate, with six cases having been presented during the past 12 months. Most grievances were settled by the parties or dropped by the Union after the third-step hearing, and five pending arbitration cases were resolved to the mutual satisfaction of the parties prior to formal hearing on the day scheduled for the arbitration. However, it is important to point out that the issue of bargaining unit work as it relates to the Research, Development and Technical Employees' Union has continued to be the center of disagreement between the parties. Sixteen grievances are presently awaiting arbitration on this very basic issue which has persisted for over five years. At present the Union and the Institute are attempting to find a mutually satisfactory solution to this issue that affects the administration of the Agreement on campus.

JAMES J. FANDEL

OFFICE OF PERSONNEL SERVICES

Personnel officers and representatives have continued their efforts to provide better information and counsel to all members of the Institute community on a broad scope of personnel matters. One goal for the year was to improve or expand delivery of service in each area of responsibility. This has included such changes as involvement in departmental standing meetings, office hours scheduled in a particular department or school location, and site visits to less familiar or

geographically separated areas. A second goal involved more aggressive planning for affirmative action programs as well as better methods of assisting departments in their implementation of affirmative action policies and practices. Many ideas were generated and new procedures are in the process of being implemented.

A number of staff changes occurred in the personnel officer and representative assignments during this past year. Richard Cerrato, Sally Hansen, and Richard Higham were appointed as coordinators for the Personnel Officer/Representative group. Larry Milan transferred to a regional director position in the Alumni Association. Evelyn Perez left MIT for job opportunities in another state, and Ann Perkins was promoted to a personnel representative position for the Sloan School of Management. Vera Ballard transferred from the Office of Personnel Development to a personnel representative position for a group of centers and laboratories reporting to the Provost. Anne Whitman joined the staff to serve as a personnel officer in the President's area, and Philip Robinson assumed responsibility as a personnel representative for the Libraries.

As in previous years, personnel officers and representatives have devoted significant amounts of time to personal and career counseling, manpower planning, labor relations grievances and arbitrations, and classification and salary reviews. Additional assignments included instructing in the Office of Personnel Development programs, serving as resource persons for the task groups of the Working Group on Office/Clerical Issues, and completing the final sections of the *MIT Personnel Policy Manual*.

RICHARD J. CERRATO
SALLY H. HANSEN
RICHARD E. HIGHAM

OFFICE OF PERSONNEL DEVELOPMENT

The Office of Personnel Development (OPD) continued to provide favorably received services and programs to approximately 1,700 MIT employees during the past year. Despite the favorable response to programs, it was decided in early April that it was necessary to discontinue the Office because of Institute financial considerations.

Programs and activities of the OPD during the past year have included the following:

- 1) The Lincoln Laboratory Management and Supervisory Development Program with emphasis on Affirmative Action and Equal Employment Opportunity continued. Program number XXXIII was completed. Approximately 825 Laboratory managers, supervisors, and technical staff members have now participated in the Program since it was originally designed and presented in 1976.
- 2) Administrative Development Programs (ADP) XIII and XIV were completed, as was the Organizational Psychology section of ADP XV. This program has served almost 400 eligible staff members since its inception.
- 3) The campus Supervisory Development Program (SDP) continued with collaboration of the Office of Personnel Services and other Institute resources. Programs III and IV were presented to approximately 50 supervisors during the past year.
- 4) The Administrative Procedures Program (APP) was presented in four sections to more than 115 support staff and exempt employees. The total number of participants in APP since it was first offered is almost 600.
- 5) Community-wide Communications Skills Workshops were presented during the past year to two diverse groups of 25 employees in each. The 50 participants were representative of most Institute payroll categories.

- 6) The Tuition Assistance Plan was changed to increase the maximum reimbursable amount to \$900 per calendar year for full-time employees. The plan was utilized by more than 700 employees during the past year.
- 7) Technical Typing classes -- not available elsewhere in the Boston area -- continued to be offered to motivated employees whose jobs require development and use of that skill.
- 8) Specially designed Team Building Workshops were presented to staff members of two separate departments, which requested them.

Participant evaluation responses for all programs have been "good" or "excellent" 90 percent of the time. Individual employees have reported both personal and professional growth accruing from the programs. Most have cited specific situations in which they have been able to apply learnings from OPD programs to their particular work settings. Instructional personnel from various areas of the Institute also have reported clear advantages to their own organizations from the exposure provided by OPD programs. In addition, collaboration among the several parts of the Personnel organization, and with Lincoln Laboratory, has been facilitated by OPD program efforts. Networking among members of the MIT community is frequently mentioned as a positive outcome of OPD programs.

All campus programs have continued to be oversubscribed, with about twice as many applicants as available slots. The mandatory Lincoln Laboratory program has continued to be extremely well attended and very favorably received. It is noteworthy that 97 percent of all participants in the 33 programs presented to date, have rated the OPD staff teams as "good" or "excellent" with 63 percent rating OPD teams as "excellent."

The OPD has continued to provide support staff for the Working Group on Office/Clerical Issues, and resource persons to task groups. The Co-Directors served as members of the editorial board, which produced the new *MIT Personnel Policy Manual*. They were also profiled in a book on job sharing, which was based on a research project by the Upjohn Institute for Employment Research. Other activities during the past year have included the following: providing staff resources to the Women's Forum in planning and presenting a day-long symposium on Stress Management, as well as follow-up sessions on the same general topic; designing and presenting, in cooperation with staff from the Office of Career Planning and Placement, an IAP workshop on career decision making; supporting a series of Career Development Workshops initiated by the Working Group and conducted by an external consultant; and responding to requests for individual career development counseling.

MAUREEN M. YAGODKA
F. ADAM YAGODKA

WAGE AND SALARY ADMINISTRATION

The compensation structures of all categories of Institute faculty and staff 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, individual performance levels and job responsibilities of over 5,000 salaried staff were reviewed, and appropriate merit increases determined and put into effect.

The modification of the Staff Salary Administration Program that was adopted two years ago continues to be very successful. Two hundred and four positions have been reviewed by the Wage and Salary Section since this modification was implemented in 1978. Of these, 100 positions were reviewed this year, including 63 requests to evaluate newly established positions and promotional recommendations, and 37 requests to reassess existing positions. In addition to establishing equitable salary ranges, these reviews have increased our already large pool of information concerning position requirements and responsibilities.

The new support staff position standards, which were developed by the Classification Task Group of the Working Group on Office/Clerical Issues and adopted at the beginning of the year, have proved to be a great success. These standards are both fair and workable and have contributed substantially to equitable decisions concerning individual support staff positions. It is clear from our experience to date that these standards have also contributed to a more complete utilization of all salary ranges within the Institute's support staff classification structure.

KERRY B. WILSON

EMPLOYMENT ACTIVITY

The non-academic employment population on campus, as of March 31, 1980, was 4,923, an increase of approximately nine and a half percent over the past year. There was also an increase of eight and a half percent in available positions, resulting in a busy year in trying to fill these positions. Campus employment activity showed a slight decrease in numbers of applicants to the Personnel Office, from 3,390 last year to 3,334 this year. Of the 3,334 persons who applied to our office, 2,652 were interviewed by Personnel Officers; of these, 2,466 were referred to supervisors and 859 of those referred were hired. This is a 15 percent decrease over the past year's hires of 1,011. In addition, the Office processed more than 3,544 additional resumes which were received, reviewed, and referred to supervisors for available positions in advance of personal interviews.

During this period, 901 Institute employees applied for transfers to other suitable positions at MIT. A total of 276 were placed successfully in new positions, a decrease over the past year's number of 326. The number of employees transferred and applicants hired combined for a total of 1,135 placements. This represents a 15 percent decrease in total hires over a total of 1,337 reported last year.

The sources of referral of applicants for employment on campus continued to follow historic trends. Referrals from *Tech Talk* MIT relatives and friends, former employees, and student referrals accounted for more than half of the candidates applying this year. Responses to advertising efforts produced 12.3 percent of all applicants while agencies supplied another 5.5 percent. MIT-related sources accounted for 52.5 percent of all applicants.

KERRY B. WILSON

News Office

The nation's news media gave significant attention to MIT-related affairs during 1979-80, not the least of these being the October 1979 election of Dr. Paul Edward Gray to be the Institute's 14th president and the May-June 1980 events surrounding the formal retirement of Dr. Jerome Bert Wiesner as the Institute's chief executive.

Other major stories of the year include explanations for an apparent double quasar image in astronomy; the worldwide release of a movie (*Meteor*) based on an MIT student engineering study; the appointment of Dr. Shirley McBay as the new Dean for Student Affairs; studies showing US airlines to be the world's safest; the Karl Taylor Compton Lecture by Dartmouth's President John Kemeny on lessons learned from Three Mile Island; the successful conclusion of the MIT Leadership Campaign at \$250.2 million, well beyond goal; the possible use of robotics in the food industry; and studies suggesting that hospital workers may have a great deal to do with hospital computer malfunctions.

Special continuing attention was devoted by the News Office to inquiries having to do with the status of Iranian students at MIT in the wake of the takeover of the US Embassy in Iran, and to the continuing harassment of physicist Andrei Sakharov in the USSR.

One story that brought the Institute widespread attention in the nation's newspapers was the surrender of the WTBS call letters by the student radio station so they could be assigned to Atlanta entrepreneur Ted Turner for use with his flagship TV station in Atlanta. The station anchors Turner's new Cable Network News system. Turner made a major gift to the MIT station, which students used for upgrading the station's equipment and signal. The new station call letters are WMBR for Walker Memorial Building Radio.

All told, the News Office issued 195 news releases during 1979-80. Fifty-four of these dealt with the substance of scholarly research.

Of special interest is the fact that 64 of our 1979-80 press releases dealt with art, music, drama, and related cultural events and activities at the Institute. This effort was carried out by Paula Ruth Korn, assistant director, in support of the program for developing an Arts and Media Technology Facility at the Institute. In addition, Ms. Korn made innumerable contacts with the press on behalf of the arts at MIT and, under sponsorship of the MIT Council for the Arts, made four trips to New York City and two to Washington, DC, to gain national publicity for the Institute's programs. Also on behalf of the Council for the Arts, Ms. Korn produced eight videotapes, six of them documenting specific art/technology programs at MIT, one a composite, and one on a chamber music performance.

Students in the MIT Writing Program contributed importantly to the nine issues of *Reports on Research* published by the News Office this year on behalf of the MIT Industrial Liaison Program. Through Professor John Wilkes in the Writing Program, students are receiving practical experience in reporting and writing on research work in popularized form and receiving the satisfaction of seeing their work published. This practice will be continued in the coming year.

Tech Talk, published by the News Office, appeared 40 times during 1979-80, including one two-page special edition on the election of President Gray. All told, *Tech Talk* carried 330 pages for the year. In addition, five supplements to *Tech Talk* were incorporated with regular issues: the Report of the President and Chancellor, October 17; Committees of the Institute, December 5; Accreditation Report, February 27; Open House Program, April 30; and The Wiesner Years, May 28.

Tech Talk is basically a free publication. It is distributed free at the Institute in Cambridge and at Lincoln Laboratory in Lexington. In addition, the publication is sent free of charge by third class mail to some 2,000 retirees. But over the years there have been a certain number of people who have wanted to receive it weekly by first class mail (*Tech Talk* does not enjoy second class mailing privileges), and for these a subscription charge is made to defray the postage and handling expense (\$12 per year). Subscriptions have been increasing and at the end of 1979-80 the number reached 464, up 12 percent from the previous year. Of these, 266 are paid personally by the subscriber and the rest on behalf of subscribers by various offices at the Institute.

There were no staff changes in the News Office during 1979-80.

ROBERT M. BYERS

Campus Information Services

During the past year, there was continued high demand for the services of all of the offices (and people) within this area -- many of whom devoted a great deal of time and energy to activities associated with the changes in the senior administration. In the following pages are the reports of each of the organizations within the Campus Information Services: Conference Coordination, Design Services, the Information Center, and the MIT Bulletin Office.

CONFERENCE COORDINATION

The Office of Special Events was a hub of activity during the past year as Barbara Weinblatt, Assistant for Special Events, provided simultaneous support to numerous national and international conferences on campus and worked with offices throughout the Institute to develop a working system for conference coordination. A highlight of the year was the July 1979 Conference of the World Council of Churches on "Faith, Science, and the Future," which brought together some 1,500 theologians and scientists from all over the world to discuss the problems and prospects for a "just, participatory, and sustainable" society. The confluence of many different cultures, religious traditions, and languages provided stimulation and challenge to all who participated in, or provided services in support of, the conference.

Other conferences held during the year, ranging in size from 50 to 500 participants, included: Conference on the Role of Policy Analysis in Education of Planners, Conference on Functional Analysis and Its Applications, US-USSR Joint Conference on the Fundamentals of Microbiological Processes, Conference of the International Laboratory in Architecture and Urban Design, Conference on Cooperative Research, Eighth Annual Northeast Bioengineering Conference, New England Board of Higher Education Conference on Energy Conservation, Conference on Import Competition, Seventh International Conference on Magnetohydrodynamic Electrical Power Generation.

In addition, planning continued for a number of major conferences scheduled for the summer of 1980.

In January 1980, the Office was blessed with the addition of Gayle Bengtson, who, as Senior Secretary, provides invaluable staff support and good cheer in all dimensions of the conference coordination effort. In May, Barbara Weinblatt left her position and the Institute in anticipation of the birth of the Weinblatt's first child, Hillary. Barbara's fathomless energy, enthusiasm, and sense of organization were a source of joy to all who worked with her. Succeeding Barbara as Assistant for Special Events is Carole L. Taylor, whose background in industry and private business should prove an asset in further developing the conference coordination services at the Institute.

DESIGN SERVICES

In 1979-80 the Office of Design Services, under the direction of Jacqueline Casey, undertook 325 graphic design and publishing projects consisting of 490 parts. These publications included projects for the MIT Leadership Campaign, the Alumni Association, and assignments from many individual offices and departments within the Institute. The office continues to provide design and production assistance to the growing number of conferences held at MIT.

During the last five years, the office has been active in publishing several major documents for the Leadership Campaign. These publications have been under the supervision of Nancy Pokross and were designed and produced by Betsy Hacker. The Campaign, with a goal of \$225 million, came to a successful conclusion in April with a figure of \$250,232,000. The office will continue to work closely with the Development Office on future publications.

Gail Zimmermann, Production Manager with special responsibility for Alumni Association publications, left the Institute in March to further her career in management. She was replaced by Mario Furtado, formerly of the MIT Press.

Professional recognition once again highlighted the design efforts of several members of the staff during the past year. The work of Ms. Casey, Ralph Coburn, Betsy Hacker, and Nancy Pokross was broadly represented in major design exhibits, books, and journals. These include *Photographis* (Casey); *Graphis Annual* (Pokross); *CA Annual* (Casey); *Modern Publicity* (Casey, Coburn, Pokross); New York Art Directors Club (Pokross); New York Society of Publications Designers (Pokross); Art Directors Club of Boston (Casey, Silver Medal, Two Distinctive Merits, Pokross, Four Distinctive Merits, Two Merits); CASE (Council for Advancement and Support of Higher Education), Two

Citation Awards (Casey), Citation Award (Pokross), Special Merit Award (Hacker). Noteworthy is the fact that the *Technology Review* (Pokross, Art Director) has won 19 awards in this past year.

Mrs. Casey was represented in three one-woman exhibitions: the Hayden Corridor Gallery, Burton House Gallery, and the London College of Printing in England. One of her posters was acquired for the permanent collection at the Museum of Modern Art in New York, one in Citibank/Citicorp, and three were selected for the Warsaw Biennale in Poland. Her work was also displayed in the Women in Design International Poster Exhibit, County Museum, Los Angeles. She served as a juror for the Art Directors Club of Boston and continues as a panelist reviewing government graphics in Washington as well as board member at the American Institute of Graphic Arts in New York. She will be included in the 12th edition of Who's Who of American Women.

A one-man exhibition of paintings by Ralph Coburn was held in March at the Alpha Gallery in Boston.

Nancy Pokross lectured at the Swain School of Art and at the CASE Seminar on Direct Mail. She was a judge for the CASE Annual Competition of Total Publications Programs.

INFORMATION CENTER

The decade of the 1970s marked many significant changes for the Information Center in reorganization, development, and growth. As part of a larger organization charged with improving communications within the campus as well as helping to meet the information needs of the public, the Center began the decade by continuing to serve as the central distribution point for the printed MIT reports, publications, and notices, and served as an internal communication link for the Institute. At this time, the Center began evening, weekend, and holiday service, absorbing the function previously handled by the Physical Plant Office during these off hours.

At the close of 1976, the Institute was saddened by the death of Carolyn Cox, director of the Registry of Guests. A major change, the consolidation of the Registry of Guests and the Information Center for day-to-day general operation and support, occurred at this time.

In March of 1978, the Information Center moved to the newly designed and renovated space previously occupied by the Registry of Guests. This move connected the News Office to the Information Center, combining one area for the dissemination of information, distribution of materials, and a central filing area.

There was still another service to be established before the close of the decade, the formation in 1978 of a conference coordinator's office. Reporting to the Manager of Campus Information Services and working closely with the Director of the Information Center, the Assistant for Special Events works with the faculty sponsor on detailed logistical planning and coordination of all of the MIT services needed to support a conference on campus.

During this past year, the Center discontinued its evening, weekend, and holiday operations due to limited use.

A major highlight of this year was the holding of Commencement exercises in Killian Court for the first time in more than 50 years.

By the close of the decade, the Information Center was involved in many Institute-wide activities, and the director of the Center had established herself as a major resource for the planning and execution of many special events and information-related projects.

The campus tour service, provided primarily for prospective students and their families, was particularly active during the past year. The head guide, Susan M. Krolewski, Class of 1980, continued in the tradition of hiring and training MIT students to conduct tours of the Institute. We have been fortunate in the caliber and enthusiasm of the students employed, which totalled 24 this year. Grace J. Napier, Class of 1981, and Christian Hoke, Class of 1981, deserve special

recognition, not only in conducting tours but also serving as public relations assistants in the Center for the active summer months. Also deserving special mention is Steven L. Solnick, Class of 1981, for his help with the tours over the summer.

The following is a tabulation of visitors who saw the Institute through an MIT tour from July 1979 through June 1980.

Prospective Students	2,594
International Students	1,467
General Visitors	<u>3,073</u>
Total	<u>7,134</u>
Visitors on General Tours	5,516
Visitors on Special Tours	<u>1,618</u>
Total	<u>7,134</u>

The staff in the Center continued their diligent work on the many aspects of information which include a planning calendar, which helps the Institute community avoid conflicts in planning major events by submitting material for a central calendar or calling and checking for possible conflicts. In addition, the Center continues to maintain and authorize the use of various Institute mailing lists, to maintain and publish a comprehensive "catalogue" of Institute committees, to identify and route the hundreds of pieces of misaddressed mail which comes to the Institute each day, and to distribute catalogues, reports, and other publications. During this past year, the following volume in publications were distributed:

Bulletin issues	18,684
Reports	7,365
MIT maps and guides	23,432
Other publications	24,108

In support of international faculty and staff, Virginia Lyons continued her exceptional service, particularly in providing advice and guidance on issues relating to immigrant and non-immigrant visas. There was considerable immigration activity affecting international scholars and faculty, and a 20 percent increase in their number, bringing the total of international faculty and staff at MIT to 953.

Some highlights of the year in the international area include the following:

Labor Certification. The Department of Labor published changes in the regulations for labor certification in January, and MIT and Harvard prepared and submitted a joint response. Briefly, the new regulations would simplify the application process for faculty, eliminating the requirement for additional advertising and salary information and they would further complicate the procedures for researchers. Although the changes were expected to be in effect by the summer, a final version of the regulations has not been published and is not foreseen until January 1981. In the meantime the current regulations remain in effect.

People's Republic of China. The resumption of diplomatic ties between the United States and the People's Republic of China (PRC) in 1979 brought increased contact with educational institutions, MIT among them. Early in 1979 there were no Chinese scholars at the Institute. At the end of the academic year there were 53, making the PRC the sixth highest ranking country of the 68 nations represented among staff and faculty at the Institute. In addition, there were many Chinese delegations visiting the Institute during the year, including visits from Tsinghua (Quinghua) University, (the "MIT" of China), and the Minister of Education. More delegations and scholars are expected in the future.

Select Commission Report. In November, a report to the Select Commission on Immigration and Refugee Policy was prepared by Harvard and MIT on behalf of a number of institutions in the Boston area. The Commission is charged with reviewing the immigration laws of the United States and is seeking advice from interested parties as to how the laws might better serve those affected by them. We hope that some of our suggestions may be incorporated into the final report of the Commission.

NAFSA. Ms. Lyons served as the Massachusetts representative to the National Association for Foreign Student Affairs (NAFSA) for the 1979-80 academic year; and in mid-year she was also appointed to the Government Regulations Advisory Committee for a two-year term.

International Visitors. During the year, the programs for the short-term visitors were ably arranged by Terri Priest. Three hundred and seventy-two visitors came to the Institute during the 1979 calendar year and 356 appointments were scheduled for them.

Organization. As more and more international staff and faculty have come to MIT and as the regulations affecting their stay have increased in complexity, the need to reorganize the services offered to them by the office has become acute. We plan to give this situation considerable attention in the coming months and expect that we will be able to maintain a high standard for the information we provide while reconsidering how we do it.

In December, Deborah Abelman, who provided indispensable staff support to Ms. Lyons in the international services of the office, left the Institute and was succeeded by Maureen McDonough. All of the support staff in the Center, Kathleen Barrett, Donald Ferland, Maureen McDonough, and Terri Priest continued to provide services with an exceptional sense of cooperation, loyalty, and good spirit.

MIT BULLETIN

In 1979-80, the Bulletin Office produced the three Institute catalogues, the small and large versions of both the *Report of the Treasurer* and the *Report of the President and Chancellor*, and the *Student Directory*.

During the last three years we have noted a steadily increasing demand for the *Courses and Degree Programs* issue of the Bulletin. This book was originally intended as a guide for MIT students in planning their educational programs. However, prospective students also seem determined to review the detailed academic information found in this book even before they are admitted to the Institute. Requests for the book by this group of students have used up a very substantial portion of the print run. In fact, for the last few years we have exhausted our supply of books several months before the new edition is published.

Coupled with this problem is the fact that we feel we are duplicating our publication efforts with regard to prospective students. We have been providing them with an overview of the academic and extracurricular aspects of MIT in the *General Catalogue*. However, after receiving the *General Catalogue*, the prospective students frequently call or write the Institute requesting the detailed catalogue, *Courses and Degree Programs*. So, instead of one book meeting their information needs, we were producing and mailing two rather sizable publications.

For 1980-81 we plan to combine the two catalogues into one book which, we hope, will be more useful to both current and prospective students. This "new" book, which will continue to be called *Courses and Degrees*, will include all the detailed academic information as well as sections on housing, campus activities, student services, and financial aids.

As noted last year, we had planned to typeset the 1979-80 *Student Directory* by computer composition, rather than printing from reduced computer printouts. However, the outside supplier of computer composition services backed out of the project at the last minute because of major computer problems on their end. Though we had wanted to improve the readability and appearance of the book, timeliness on this publication is a critical factor; we opted to continue using a computer printout in order to maintain our original schedule.

In March, Susan Shansky, the Bulletin's Editorial/Production Assistant, resigned after three and a half years of excellent service in our office. Ms. Shansky left to accept a staff position as Publications Supervisor in the Industrial Liaison Office. We appreciate the dedication and hard work which characterized her performance, and wish her the best in her future endeavors.

Also in March, Mark Wilson was hired as the new Editorial/Production Assistant. Mr. Wilson was formerly Production Assistant to the Director of Book Production at the Word Guild in Cambridge.

Janet Snover, Editor/Production Manager, finished her term as president of the New England College Publications Association. In April, she and Nancy Pokross of Design Services, served as judges of the "Total Publications Program" category of a nationwide competition sponsored by *Time* Magazine and the Council for the Advancement and Support of Education. A total of 57 colleges and universities entered their publications for judging.

KATHRYN W. LOMBARDI

MIT Press

During this year when the economy suffered the shocks of inflation and recession, the MIT Press successfully met its goals for fiscal 1980. The book division published 94 books: 73 new books and 21 paperback reprints. Total sales were 427,000 copies, for a record income of \$4,031,900. While sales of hardcover books grew moderately, reflecting industry trends, sales of paperback books increased dramatically for the second straight year. Approximately 35 percent of the Press's sales are now from paperback books, with text and supplementary text adoptions showing the most significant growth -- up 29 percent, twice the industry average. International sales accounted for about 28 percent of total sales, an impressive figure for an American publisher.

The journals division added several new journals to its program, effectively doubling its size in a two-year period. Gross sales of journals exceeded \$1 million, a 20 percent increase over 1979. Reflecting its growing size and stature, the journals operation was this year designated an independent, fully-accountable division of the Press.

MIT Press books and journals received awards and recognition from the academic community and many professional organizations, dominating the Association of American University Presses Book and Journal Show this year by winning five out of 35 places for books and one out of five places for journals. Winners were *Ancient Greek* revised edition by Carl Ruck; *Building Tomorrow: The Mobile/Manufactured Housing Industry*, by Arthur D. Bernhardt; *Infinitesimal Calculus*, by James M. Henle and Eugene M. Kleinberg; *Moments of Vision*, by Institute Professor Harold E. Edgerton and Honorary Chairman of the Corporation James R. Killian, Jr.; *Seasonal Cycles in the Housing Market*, by Kenneth T. Rosen; and the journal *October*, Rosalind Krauss and Annette Michelson, editors. *Moments of Vision* was selected from worldwide competition by Time-Life as one of two photography books featured in its *Photography Year 1980*. *Science, Sin, and Scholarship*, by Irving Louis Horowitz, and *Beyond Orpheus: Studies in Musical Structure*, by Professor David Epstein, were named by *Choice* (Association of College and Research Libraries) as "Outstanding Academic Books" of the year. *Beyond Orpheus* was also the winner of an award for its index, prepared by MIT music librarian Linda Solow. *Richard Morris Hunt*, by Paul R. Baker, which was assisted by a grant from the National Endowment for the Humanities, has been nominated for the Merle Curti Prize of the Organization of American Historians and submitted for the Pulitzer Prize in biography.

Frank Urbanowski completed his first full year on the governing boards of both the Association of American University Presses (AAUP) and the Association of American Publishers (AAP). Under his chairmanship, the Technical, Scientific, and Medical Division of the AAP graduated to a broader role and constituency and a new name, the Professional and Scholarly Publications Division.

The MIT Press Management Board met twice during the year. Jack Schulman, Emeritus Director of Cambridge University Press, concluded his long and distinguished tenure, and the Board welcomed new members Alexander J. Burke, President of McGraw-Hill, and Norman Pomerance, Senior Vice President of Harper & Row. Continuing Board members were Professor Arnaldo C. Hax, Sloan School of Management; Professor Walter Owen, Department of Materials Science and Engineering; Professor Myron Weiner, Department of Political Science; Professor Hartley Rogers, Jr. (ex-officio), Chairman

of the MIT Press Editorial Board; and W. Bradford Wiley, Chairman of the Board of John Wiley & Sons. Constantine Simonides, Vice President of the Institute, is Chairman of the Management Board.

BOOK DIVISION

The Press concluded fiscal 1980 with a net operating surplus of \$155,800 from its book division. The sales budget of \$4 million was slightly exceeded, with an increase in sales over 1979 of 13.5 percent. The combination of meeting the sales target and closing the year with cost of sales and operating expenses below original forecasts, plus slightly higher earnings in subsidiary rights income, all contributed to produce a new surplus, which has been reserved for the development of future publishing programs and opportunities.

	<u>FY 1980</u>	<u>FY 1979</u>
Total Net Sales	\$4,031,900	\$3,552,200
Cost of Sales	<u>1,512,700</u>	<u>1,280,500</u>
Gross Margin	2,519,200	2,271,700
Other Income	<u>40,300</u>	<u>29,700</u>
Total	2,559,500	2,301,400
Operating Expense	<u>2,403,700</u>	<u>2,211,400</u>
Net-Books	\$ 155,800	\$ 90,000
Percent Net Sales	<u>3.9%</u>	<u>2.5%</u>

BOOK PROGRAM

The emphasis on careful planning for list development was continued, with the first results of a well-focused acquisition program beginning to show in the 1980 list. At the end of the year the Press hired a new editor for the lagging list in life and health sciences, and we expect a significant acceleration in the acquisition of books in this area.

New Books Published FY 1980 by Category and Subject Area

	<u>Scholarly & Professional</u>	<u>Reference</u>	<u>Text</u>	<u>Trade</u>	<u>Total</u>
Architecture & Urban Planning	13	0	0	2	15
Economics & Business	2	4	1	1	8
Energy & Environment	6	1	0	0	7
Engineering & Technology	7	0	2	2	11
Humanities	5	0	0	5	10
Science & Mathematics	4	3	0	4	11
Social Science	7	1	0	3	11
Totals	<u>44</u>	<u>9</u>	<u>3</u>	<u>17</u>	<u>73</u>

Outstanding books for general readers (trade) included several by MIT faculty. *The Computer Age: A Twenty-Year View*, edited by Professor Michael L. Dertouzos and Joel Moses, was widely reviewed and sold over 5,000 copies in its first year of publication. *The Computer Age* was featured as an alternate selection in the Computer Professionals Book Club and will be issued in paperback this fall. *Astronomy of the Ancients*, edited by Kenneth Brecher and Michael Feirtag, sold nearly 3,000 copies and was a main selection in the Astronomy Book Club. Other outstanding trade books were *Monsters in the Sky*, a translation from the Italian work by Paolo Maffei; *Americans on the Road: From Autocamp to Motel 1910-1945*, by Warren James Belasco; *The Computerization of Society*, by Simon Nora and Alain Minc; and *Biblical Games*, by Steven J. Brams. *Monsters in the Sky*, which sold 2,000 copies in the first four months of publication,

was featured as a main selection by the Astronomy Book Club, the Library of Science, and the Natural Science Book Club. Paperback rights to the title, and to Maffei's earlier work *Beyond the Moon* (MIT Press, 1979), were sold to Avon.

This year saw one of the Press's most successful, and rapidly published, new paperbacks: *North-South: A Program for Survival*; the Report of the Brandt Commission was copublished by MIT Press and Pan Books Ltd. of London. The confidential report was bound on February 6 and 7 in England, shipped on the 8th, and arrived on the 11th in time for a noon press conference at the United Nations. The first printing was already sold out. *North-South* has received extensive media coverage, sold over 18,000 copies, and is now in its fourth printing. Other outstanding paperbacks from the new list were *Knowledge and Wonder*, second edition, by Institute Professor Victor F. Weisskopf; *Ten Thousand Working Days*, by Robert Schrank, and *Architecture and Utopia*, by Manfredo Tafuri.

Many books from the Press's backlist were adopted in paperback as supplementary texts this year. Akmajian, Demers, and Harnish's *Linguistics*, one of the few introductory level texts published by the Press, has sold over 15,000 copies in its second year of publication. An outstanding new text was Peter Kennedy's *A Guide to Econometrics*. Reference works included *Medicinal Plants of East and Southeast Asia*, by Lily M. Perry, and the collected works of Institute Professor Franco Modigliani, Joan Robinson, Oscar Zariski, and Norbert Wiener.

Scholarly and professional books are the core of the Press's program. Outstanding books that demonstrate the breadth of the list include: *Dyslexia*, by Frank R. Vellutino; *Plasma Physics for Nuclear Fusion*, by Kenro Miyamoto; *The History of The City*, by Leonardo Benevolo; *The Structure of World Energy Demand*, by Professor Robert S. Pindyck; and *Deepsea Mining*, edited by Professor Judith T. Kildow. Books published within series this year are *Studies in Italian Art and Architecture*, edited by Professor Henry A. Millon (American Academy in Rome Studies in Art History Series); *The Prospective City*, edited by Professor Arthur P. Solomon (MIT-Harvard Joint Center for Urban Studies Series); *Regulatory Bureaucracy*, by Robert A. Katzmann and *The State and Human Services*, by Laurence E. Lynn, Jr. (American Politics and Public Policy Series); *Panini as a Variationist*, by Professor Paul Kiparsky (Current Studies in Linguistics); *Electric Power in the United States*, by Martin L. Baughman, Professor Paul L. Joskow, and Dilip P. Kamat (MIT Energy Laboratory Series); *Ecosystem Succession*, by Luis T. Gutierrez and Willard R. Fey and *Elements of the System Dynamics Method*, edited by Jørgen Randers (MIT Press/Wright-Allen Series in System Dynamics); and *Traffic Flow on Transportation Networks*, by G.F. Newell (Series in Transportation Studies). MIT Press series editors are Professor Patrick Henry Winston and Mike Brady (Artificial Intelligence); Professor Samuel Jay Keyser (Current Studies in Linguistics); Professor Jay W. Forrester (MIT Press/Wright-Allen Series in System Dynamics); Professor Alan S. Willsky (Signal Processing, Optimization, and Control); Professor Martha Wagner Weinberg and Benjamin Page (American Politics and Public Policy); William E. Griffith (Studies in Communism, Revisionism, and Revolution); and Professor Marvin L. Manheim (Transportation Studies).

New series in which titles will appear in 1981 or 1982 are Structural Mechanics, Professor Hilary M. Irvine, editor; Opposition Books (Institute for Architecture and Urban Studies); Health and Public Policy, Professor Jeffrey Harris, editor; Regulation of Economic Activity, Professor Richard Schmalensee, editor; Housing and Urban Policy, Professor Bernard Frieden, editor; Documents in American Industrial History, Professor Michael Folsom, editor; Linguistic Inquiry Monographs, Professor Keyser, editor; and Studies in Contemporary German Social Thought, Thomas McCarthy, editor.

Faculty serving on the MIT Press Editorial Board in 1979-80 were Professors Jagdish N. Bhagwati, Fernando Corbato, Harold J. Hanham, Leo Marx; Professors Millon, Ernest Moniz, Ascher Shapiro, Robert A. Weinberg, and Sylvain Bromberger, who was substituted for by Professor Morris Halle during the fall term. Jay K. Lucker and Constantine Simonides served as ex-officio members. Professor Hartley Rogers, Jr. is chairman of the MIT Press Editorial Board.

Acquisition editors are Frank Satlow, Executive Editor (Engineering and Technology), Laurence Cohen (Physical Science and Mathematics), Roger Conover (Architecture, Urban Planning, and Design), Grahame Smith (Life Sciences and Health Policy, Technology, and Management), Sharon Basco (Popular Science), and Muriel Cooper (Special Projects in Visual Communication). At the end of the year, Barbara Ankeny and Rene Olivieri left the Press for editorial duties in other publishing houses.

BOOK PRODUCTION

Sixty-eight manuscripts entered the production process this year, receiving the expert attention of the Press's editorial and production staffs (Helen Osborne, Managing Editor and Richard Wolflein, Production Manager). Six manuscripts were received "camera-ready," 43 were edited in-house, and 25 were edited freelance, under the supervision of the MIT Press staff. The production department contracted for over \$1 million of goods and services in the composition, and printing, and binding of new books and reprints. Ninety-three books were reprinted during the year, including all-time bestsellers *Image of the City*, by Professor Emeritus Kevin Lynch (112,587 copies sold, 15 printings); *Experiencing Architecture*, by Steen Eiler Rasmussen (119,587 copies sold, 8 printings); *Yellow Pages of Learning Resources*, by Richard S. Wurman (150,842 copies sold, 6 printings); and *Beyond the Melting Pot*, second edition, by Nathan Glazer and Daniel Patrick Moynihan (141,425 copies sold, 7 printings).

With the installation of Computergraphics, (Mildene Bradley, Manager) the Press will be able to typeset an increasing number of its books and journals in-house. A good deal of time was spent this year in contract and specifications work with Penta Systems International and Autologic, Inc. Results of the preliminary tests conducted in March were, on the whole satisfactory, with particularly impressive results in tabular and mathematical capabilities. System generation (the design and input of all information used to create a system unique to the MIT Press installation) is presently under way. Plant and installation testing of the entire system is expected to take place in late fall 1980, with delivery scheduled for January 1981.

The Press's design staff (Sylvia Steiner, Design Manager) spent part of its time this year preparing for Computergraphics by designing a series of standard formats which promise to simplify and speed up the production process for many of the Press's books. As always, MIT Press garnered a number of design awards during 1979-80. In addition to capturing the largest number of places in the AAUP Book and Journals Show, the Press received multiple awards for jacket design from the New England Book Show, the Boston Art Directors Club, and *Graphis*, which sponsors an annual international competition for the best work in advertising, publishing, and three-dimensional design.

BOOK MARKETING AND FULFILLMENT

The combined efforts of the Press's promotion and sales staffs (Tom McCorkle, Marketing Manager and Brooke Stevens, Promotion Manager) resulted in steady sales growth, despite the general economic malaise. There were two exceptions: a dramatic rise in paperback sales; and sales to wholesalers, which showed relatively little growth.

<u>Customer Type</u>	<u>FY 1980</u>	<u>FY 1979</u>
Government	--	\$ 29,000
College Bookstore	\$ 723,852	563,000
Retail Bookstore	800,906	671,000
Wholesale and Jobber	717,111	668,000
Public Library	--	7,000
College & University Library	117,941	110,000
Direct Mail	296,295	222,000
Other	324,586	256,000
TOTAL	\$2,980,691	\$2,526,000

Over 400,000 brochures and catalogs were mailed to individuals and institutions in fiscal 1980, producing a traceable direct mail income of \$300,000, half of that coming from special "clearing" sales. Books in architecture, computer science, and neuroscience brought the strongest response. Over 100 advertisements were placed in trade and professional media, and MIT Press books were displayed at over 50 trade and professional meetings during the year. Aggressive publicity efforts resulted in over 2,000 reviews of Press books in local, national, and international publications.

Direct mail promotion of texts, primarily of new and backlist paperbacks, now in its third year as a formal program under the direction of Texts and Exhibits Manager Bruce Katz, resulted in a second year of dramatic increases in adoptions. This takes place within an overall increase in paperback sales, as shown in the proportion of paperback sales to total domestic sales, fiscal 1977 to fiscal 1980.

<u>Paperback Percentage</u>		
<u>Year</u>	<u>Units</u>	<u>Dollars</u>
FY 1977	48.6%	21.4%
FY 1978	42.5%	18.3%
FY 1979	60.3%	33.8%
FY 1980	62.8%	34.9%

Particularly impressive is the contribution of paperback sales to all backlist sales. In 1980, 70 percent of backlist unit sales were paperback; and 44 percent of backlist dollar sales were paperback.

The relatively small increase in sales to wholesalers is apparently the result of tightened institutional budgets. Most of MIT Press sales through wholesalers are, in fact, library sales. Throughout the industry, hardcover unit sales are dropping.

International sales represented approximately 28 percent of total sales in fiscal 1980. Don Stanford, Assistant Sales Manager for International Sales and Subsidiary Rights, describes overall sales levels as satisfactory, although political and economic problems in several parts of the world resulted in disappointments, specifically in India and Australia.

	<u>FY 1980</u>	<u>FY 1979</u>
Australia	\$ 26,000	\$ 40,000
Canada	149,000	117,000
East Asia, Latin America	326,000	341,000
UK, Europe, Africa, Middle East	<u>623,000</u>	<u>550,000</u>
TOTAL	\$1,124,000	\$1,048,000

Translation rights to 17 MIT Press books were sold this year to Chinese, German, Italian, Japanese, Spanish, Greek, and Russian publishers. Stroyvdat (USSR) will publish a volume of selections from Professor Emeritus Lynch's *Managing the Sense of a Region, What Time is this Place?* and *Image of the City*. Japanese rights were sold to Professor Dertouzos and Moses's *The Computer Age* and to Brecher and Feirtag's *Astronomy of the Ancients*.

Book clubs bought rights to 12 MIT Press books. Permissions, paperback, and serial rights income ended the year at a higher level than had been expected due to the accumulation of small increases in a number of areas.

	<u>FY 1980</u>	<u>FY 1979</u>
Translation rights	<u>\$37,400</u>	<u>\$29,000</u>
Bookclub rights	12,700	13,200
Permissions, paperback, and serial rights	<u>35,500</u>	<u>18,300</u>
TOTAL	\$85,600	\$60,500

The processing and fulfillment of orders for MIT Press books were facilitated this year by Ultimacc, the Press's mini business computer. Fiscal 1980 represented the first full year of operation in which results could be assessed. Michael Leonard, Associate Director for Operations, reported that conversion helped stabilize fulfillment costs and increased control over day-to-day operations. The system also captured much essential data to form a base of information for management reports, sales analyses, inventory control, customer account maintenance, credit and collection, and royalty accounting. Several colleagues in commercial and nonprofit publishing have visited the Press to see the system in operation.

JOURNALS DIVISION

The Press's journals program has achieved a remarkable record of growth over the past two years under the management of Ann Reinke. The program has more than doubled in size, from five to 13 journals. Two of these were acquired this year: the *Computer Music Journal*, edited by Curtis B. Roads; and *Science, Technology and Human Values*, edited by Marcel Chotkowski La Follette, both published quarterly. The Press also took over publication of the Institute for Architecture and Urban Studies exhibition catalogs.

The distinguished journal *Cell* completed its sixth year of publication. Since 1974 *Cell* has grown from an average size of 60 pages per issue and a circulation of 200 to an average size of 350 pages per issue and an international circulation of 4,000. *Cell* is edited by Benjamin Lewin.

Other journals in the program are the *Neurosciences Research Program Bulletin*, George Adelman, editor; *Harvard Architecture Review*; *October*, Ms. Krauss and Ms. Michelson, editors; *Oppositions* (Institute for Architecture and Urban Studies); *Perspecta: Yale Papers in Architecture*; *Via* (University of Pennsylvania Department of Architecture); *International Security*, Albert Carnesale and Michael Nacht, editors; *The Journal of Interdisciplinary History*, Robert I. Rotberg and Theodore K. Rabb, editors; *Linguistic Inquiry*, Professor Keyser, editor; and *Milbank Memorial Fund Quarterly/Health and Society*, David P. Willis, editor.

In recognition of the growing importance and viability of the program, two major changes were implemented in fiscal 1980: the entire operation was moved to new office space on Main Street in Kendall Square, and Journals was designated an independent division of the Press, with its own revenue/cost center responsibilities.

On the recommendation of the MIT Press Management Board, the division adopted full accrual accounting procedures. Only income attributable to issues published during fiscal 1980 was applied. Inasmuch as a major portion of receipts was from newly-acquired journals with large start-up costs, the journals division recorded a year-end deficit of \$155,600. The deferred income, however, increased from \$315,000 in fiscal 1979 to \$412,000 on total fiscal 1980 revenue of \$1,125,000. The new procedure should provide more comparability of financial statements for journals from year-to-year by the proper matching of earned income with cost of issues served.

Another improvement which will benefit the journals division is its new Scribe, Inc. on-line mini-computer system for fulfillment. The system will provide up-to-date and accurate subscriber profiles of all journals, an automatic system for recording deferred income, and determining earned income for each issue of a journal as it is published; accurate tracking of all sources of new subscriptions; automatic scheduling of renewals; and on-line accessibility to information for customer relations.

Ms. Reinke continued her professional activities on behalf of scholarly journals, serving for a second year as chair of the AAUP Committee on Scholarly Journals, co-chairing an AAP workshop on "New Formats for Publishing: Alternative Media and Auxiliary Techniques," and representing the nonprofit sector on a Society for Scholarly Publishing panel "Marketing the Scientific Journal."

FRANK URBANOWSKI

Quarter Century Club

The MIT Quarter Century Club was founded in 1950 and became an Institute administrative department in 1978, reporting to the Office of the Vice President, Administration and Personnel.

The activities of the Club can be categorized into three main areas: it provides a service to its members, to the Institute community, and to the alumni of the Institute.

Office of the President and the Chancellor -- Vice President

In the spring an annual meeting is held, and new members are inducted into the club. A summer picnic is held in August, and a holiday meeting takes place in December. Other services are provided to members routinely by request.

The Club provides a service to the Institute through administrative and logistical support to the Institute's annual United Way campaign, to a biennial Employees Open House, and to its annual retirement dinner. In the past, the Club has been asked to organize additional special meetings of an Institute-wide nature.

Service to the Institute and to its alumni are provided. A number of international and national trips are sponsored each year by the Club. These trips are usually for vacation purposes, but the Club also provides travel assistance, on request, to other groups within the Institute.

The Club has given assistance to various departments planning educational exchanges to other countries and to the Alumni Association for alumni club activities.

The staff of the Club consists of Ann Perkins, who serves as Office Manager, and two staff assistants, M. Frances Daly and another yet to be appointed.

The department is headed by John E. Newcomb who also serves as Executive Director of the Club.

The Board of Directors of the Club includes: Franklin A. Bidwell, Paul V. Cusick, Joseph Greene, Mary J. Hovnanian, Francis B. Magurn, Lawrence Paglierani, and Professors J. Francis Reintjes and Henry J. Zimmermann.

The officers of the Club are: Jeri Whitman, president; James J. Fandel, vice president; Daniel H. Gould, treasurer; and Ms. Daly, secretary.

The membership of the Club now totals more than 1,450. Each member has served the Institute for more than 25 years.

The Club has eight honorary members. They are: Mr. Newcomb, Dr. Howard W. Johnson, Mrs. Karl T. Compton, Mrs. George R. Harrison, Joanne S. Miller, James W. Coleman, Robert J. Davis, and Ms. Perkins.

JOHN E. NEWCOMB

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Council for the Arts

The academic year 1979-80, the Council's seventh operating year, was dominated by planning and fund raising for the Arts and Media Technology building program, in addition to the Council's continued development of the arts at MIT. Under the guidance of Professor Roy Lamson, Special Assistant to the President for the Arts, a staff of four -- Peter Spackman, executive director; Elsa G. Sonnabend, associate director; Deborah Hoover, associate director; and Sandra Congleton, secretary -- worked with members of the Council, with MIT administration, faculty and students, and with outside arts agencies to pursue the goals of the Council as an advice, advocacy, and support body for the Institute.

With the leadership of President Jerome B. Wiesner and Council Chairman Luis A. Ferré, the Council's Executive Committee oversaw the regular business and deliberated plans for the future. A subcommittee of the Acquisitions Committee, chaired by Ida Rubin, met several times with a subcommittee of the faculty Committee on the Visual Arts to advise on acquisitions policy, study the problems of maintenance and conservation of the MIT Permanent Collection, and explore plans

to augment the two student loan collections of fine prints and works on paper. The Development Committee, under the chairmanship of Gregory Smith, continued to extend the annual giving program launched the year before, developed several new sources of revenue for the Council, and began review of a plan to seek outside funding to augment the Council's Grants Program. Meeting three times during the academic year under the chairmanship of Lewis Cabot, the Grants Committee made 19 grants to faculty and student projects in the arts at MIT. It also formulated new policy statements, operational procedures, application forms, and a plan to involve committee members directly with MIT arts groups submitting proposals for Council support. The Facilities Sponsoring Committee, chaired by Vernon Alden, continued to develop new prospects for the Arts and Media Technology building, aided in a number of solicitations, and oversaw the preparation of several kinds of solicitation material. Under the chairmanship of Nelson Lees, the Membership Committee recommended five new members, who were appointed to the Council by the President of MIT. They are: William Blitzler, George Henning, Nanette Laitman, Martin Rosen, and Mrs. Ralph Wyman. During the year, David Rockefeller, Jr. resigned and five Council members completed their terms of appointment to the Council -- Virginia Duncan, John Entenza, Bates Lowry, Roger Stevens, and William Turnbull -- and were thanked for their service to MIT by President Wiesner. Total Council membership at year's end was 87.

The Council's eighth annual meeting was held on November 16, 1979, and concentrated on programs and plans for the Arts and Media Technology facilities. After welcoming remarks by President Wiesner, the Council heard committee reports during its annual business meeting. Professor Walter A. Rosenblith, Provost, then introduced a series of speakers who described the various elements of the Arts and Media Technology program as it has evolved during the year. These included: Professor William Porter, Dean of the School of Architecture and Planning and head of the Client Team, appointed by the Institute to work with the building's architects; Professor Harold Hanham, Dean of the School of Humanities and Social Science, who spoke on other arts needs of the Institute, particularly in music and drama; Kathy Halbreich, Director of Exhibitions; Professor Richard Leacock, head of the Film/Video Section; and Professor Nicholas Negroponte, head of the Architecture Machine Group.

After the Council's annual photograph, there was a luncheon with Council members and MIT faculty and students in the arts. President Wiesner announced the establishment of the Thomas Meloy Professorship of Rhetoric, which the late Mr. Meloy, Class of 1917, member of the Council and supporter of the arts in Washington, DC, had established at MIT just before his death. Several members of Mr. Meloy's family, including his wife, son, and daughter, were present to hear the remarks of Professor Irene Tayler, head of the Literature Section, who had been appointed first incumbent of the Meloy Chair for a three-year period. A second highlight of the luncheon was a talk on the importance of the individual artist by Mrs. Kitty Carlisle Hart, who was the Council's guest for the day and is chairman of the New York State Council on the Arts and a member of the MIT Corporation Visiting Committee on the Arts.

During the afternoon, the Council heard President Wiesner and Council members I.M. Pei and Mr. Alden describe preliminary architectural and funding plans for the new facilities. After a reception at Hayden Gallery, the Council's annual dinner was held at the MIT President's House. The Council's sixth Eugene McDermott Award, given annually "for major contributions to the arts as a means of human fulfillment," was presented to Jerome B. Wiesner. President Wiesner responded to the award presentation with some brief remarks that closed the meeting.

The Laya and Jerome B. Wiesner Awards

The Council's Executive Committee, responding to one of the recommendations of the report of the Ad Hoc Committee on the Future, which was active last year under the leadership of Professor Lamson, voted to establish at MIT an endowed fund to award two student prizes -- one in the creative and one in the performing arts -- each year as a tribute to President Wiesner's leadership of the Council during his tenure as MIT's 13th President. Under a subcommittee headed by Mr. Cabot and including Mr. Smith, Kay Stratton, Tony Grunsfeld, Ms. Rubin, and Professor Lamson, Council members were invited to participate in this one-time effort. The fund was established at slightly over \$28,000, the income of which was designated for two \$500 awards for student work of high achievement in the arts. The first Wiesner Awards were presented May 12th at the annual Awards Convocation to two graduate students: William Parker, for work in light sculpture; and David Dreyfuss, for development assistance and performance with the MIT Early Music Society.

Fund-Raising Activities

In October 1979, MIT received a challenge grant of \$250,000 toward the Arts and Media Technology facilities from the National Endowment for the Arts. MIT was one of only four cultural institutions in Massachusetts to be awarded a challenge grant this year. Challenge grants, the Endowment's largest mechanism for supporting capital projects, must be matched four to one in new and increased funding, and much effort during the year went into soliciting the initial matching funds, with several new large pledges of support being obtained. Working closely with the program managers and the Resource Development staff, the Council staff helped arrange a number of visits by prospective donors to the campus for demonstrations of the programs planned to be housed in the new facilities. These programs are: the Creative Photography Laboratory, the Visible Language Workshop, the Architecture Machine Group, the Film/Video Section, the Experimental Music Studio, the holography program of the Center for Advanced Visual Studies, the Exhibitions Program under the Committee on the Visual Arts, and Educational Video Resources. Presentations of various kinds were also made in New York, Washington, DC, and Miami with the help of MIT senior officers and Council members. Although the effort for major capital funding dominated Council work, the staff and Council members also called on MIT alumni and other friends for support in several cities throughout the country. Over 120 gifts were received as a result of our efforts in three fund-raising categories: annual giving, Arts and Media Technology facilities, and the Wiesner Student Arts Awards.

Publications and Promotional Materials

In addition to regular publication of its monthly calendar of arts events at MIT, the Council also produced a tabloid composite of clippings from newspapers about the arts at the Institute, *MIT Arts in the News*, and revived publication of the Council's semi-annual *NewsLetter*, which is circulated to alumni of the Departments of Architecture and Humanities, to MIT faculty, administration and staff, and Council members themselves. Working closely with the staff of Resource Development, the Council staff helped produce several written statements in support of the Arts and Media Technology facilities, as well as promotional materials consisting of photographic presentations of the academic and research programs involved and of the preliminary building plans.

The Council staff also helped coordinate a series of six 20-minute videotapes describing the arts and media technology programs; a composite tape was made for use at the annual meeting, as well as with prospective donors. The tapes, produced by Paula Korn of the MIT News Office, are designed for fund-raising purposes.

A short film, *Impressions: The Arts at MIT*, was completed early in the year by Jonathan Spring and Mark Edwards, students at the Film/Video Section. The film was commissioned by President Wiesner and coordinated by the Council staff, and serves as a means of publicity and information about the Institute's arts programs. Viewings were arranged for the Alumni Officers' Conference, Technology Day, the Information Group, a session during the Independent Activities Period, and for various fund-raising purposes.

IAP Seminar

The Council staff held three seminars during the Independent Activities Period entitled "What is the Council for the Arts at MIT?" Attended by faculty, students, Council members, and representatives of several community arts councils, the seminars began with a discussion of "MIT's Place in the National Arts Movement," led by Ralph Burgard, national cultural consultant. Michael Good, Class of 1980, presented a survey on student attitudes towards the arts at MIT. The seminars continued with "Two Views of the Arts at MIT," including the film *Impressions*, and a videotape of Henry Brant's *Spatial Concerto*, performed by the MIT Symphony Orchestra with Professor David Epstein conducting. The last seminar dealt with "The Arts and Media Technology: MIT as Harbinger." Dean Porter, of the School of Architecture and Planning, presented selections from Ms. Korn's videotapes of current work and discussed MIT's plans and programs in this emerging field.

Arts and Media Technology Facilities: Design and Planning

The Council provided valuable staff support to the program and design planning efforts, working closely with the Client Team, the architects, the program directors, and the office of the Campus Architect. Two innovative projects regarding the facilities' plans were coordinated through the Council. A grant for \$5,000 was received from the Massachusetts Council on the Arts and Humanities to support research on design and program development of an adaptable, highly advanced Experimental Media Theatre. Technical specialists in such areas as acoustical control, sound processing, video projection, and fiber optics are serving as consultants to MIT's Client Team.

A second and larger project was coordinated with the Committee on the Visual Arts and represents an attempt to expand traditional definitions of public art. A grant of \$75,000 was received from the Art in Public Places program of the National Endowment for the Arts to commission six artists to work with the architects on six design aspects of the Arts and Media Technology facility. Presentation of initial design efforts has already begun, and additional funds have been requested to hire technical consultants. Both projects mentioned above will be thoroughly documented in exhibition and/or written format.

Grants Program

Slightly over \$35,000 was allocated by the Grants Committee of the Council in support of projects in the arts at MIT, including nine Officer's Grants of \$500 or less. Competition for Council funding increased by 77 percent over the previous year, and the total funds requested from the Council more than doubled. Of 32 proposals received, 19 were awarded grants, representing \$32,000 out of \$71,000 requested. Almost three-quarters of the grants were awarded on a matching basis, generating an additional \$40,000 of program support.

The following statistics summarize program support of the arts at MIT for this unique program of internal subsidy, since its inception in 1974:

<u>By Art Form</u>	<u>Percentage</u>	<u>By Project Category</u>	<u>Percentage</u>
Visual Arts	24	Student Projects/Performances/Events	30
Music	15	Materials and Equipment	20
Architecture/Planning/VLW	13	Stipends/Fees	10
Literature	11	Exhibitions Support	8
Media/Film	10	Visiting Artists	8
Dance	10	Conferences/Seminars	7
Drama	6	Individual Artists/Students	7
Special Projects	6	Planning Studies/Surveys	5
Photography	5	Catalogues	3
		Tours	2

As in years past, grants in 1979-80 were awarded for research, such as a grant providing additional funding for a project in the analysis of 3,500-year-old glass and ceramic materials from the Boston Museum of Fine Arts (MFA), which will be published as a chapter in a forthcoming MFA catalogue; for performance, such as support for a series of informal jazz concerts sponsored by the Black Graduate Student Association, and for the first annual May Festival of small performing groups in the MIT Humanities Department, including chamber music, drama, and dance; for publications, such as partial matching support of a publication documenting work of Fellows at the Center for Advanced Visual Studies on the Centerbeam environmental arts project, and seed money support to launch an annual publication to document the work of the Creative Photography Laboratory. Support was also granted for special projects, such as an experiment in film distribution in which two graduate students in the MIT Film/Video Section took a selection of the Section's award-winning films to centers of advanced filmmaking and study across the country, and support of an educational videotape in conjunction with the Hayden Gallery exhibition, Arts on the Line, organized by the Cambridge Arts Council and the US Department of Transportation as a prototype collaboration of artists and architects involved with the MBTA extensions. The tape has been used by numerous architects, planners, and local community groups as a demonstration of a major public arts project.

Staff Transitions

Rebecca Burke, desiring to work only part-time, left the Council to work at the Center for Advanced Visual Studies. Her place as secretary was taken by Ms. Congleton. Ms. Hoover was promoted during the year from Assistant Director to Associate Director.

PETER SPACKMAN

Information Processing Services

This past year, Information Processing Services (IPS) has experienced significant changes in the patterns of usage by its administrative and academic users and also in its staff and hardware resources.

This was our first year of operation since 1972 without any Harvard University business and with a corresponding significant reduction in billed revenue; a year which produced a major shift in academic computing from traditional batch processing to on-line interactive computing, resulting in a system overload during prime shift and an excess capacity in off hours; a year which demonstrated for the first time the compatible sharing of hardware and software between administrative and academic computing on the 370/168; a year which introduced 8½" x 11" high speed Xerographic on-line printing; a year which included the delivery of new Multics hardware from Honeywell; and a year which experienced 30 changes in administrative and support staff personnel.

The following items provide the details of these changes as well as the activity and progress for each area of operation.

Administrative Information Systems

During the early part of June a study team from EDUCOM (Interuniversity Communications Council) was contracted to do an overview of the current activities, plans, methods, and tasks of both the production (ACS) and the system design (BSD) aspects of Information Processing Services.

We have been making some major decisions in hardware, software, and shared computing resources during the past few years. Because of these changes, which have disrupted fairly stable functioning groups, many resources have been consumed in conversion efforts, in learning new methods, and in implementing new techniques. MIT was fortunate to acquire on this study team recognized professionals from three major universities (Princeton, Yale, and Stanford), all of whom have broad experience in all forms of shared and separate ADP functions.

This team interviewed key supervisory personnel within IPS and also a representative cross-function of clients and Institute officers. We expect a formal report from EDUCOM by late July, and, hopefully, will find confirmation of some of our major decisions and appropriate recommendations for us to address immediately and in the future.

We were pleased with the insight demonstrated by the team members, by the manner in which they conducted their interviews and by the appropriateness of their probing, detailed questions. We look forward to the results of their review and to the opportunity of improving administrative data processing at MIT by incorporating their suggestions.

Administrative Computing Services

This fiscal year, for the first time, we have begun to see the effects of the decentralization of data access by our users due to the continued expansion and development of remote terminal-oriented systems. Scheduled production batch jobs decreased from our normal 10 to 15 percent growth to a mere 1 percent and, for the first time, the number of outstanding modification and maintenance

tasks was reduced by almost 25 percent. The principal applications responsible for this were Student and Alumni Records. In the case of Student Records, access now involves 24 terminals, permitting on-line interactive inputting, editing, and data retrieval as well as scheduled special report generation. These same functions are available in the Alumni system which is now providing over 90 percent of the offices' special requests without personal interaction between the office itself and the data processing staff. From a hardware standpoint, the expansion of the Registrar's network, continued conversion of our DOS applications to OS, as well as the increased usage of the CMS timesharing system by our programming staff, required the addition of one million bytes of main storage to the 370/148. With this added memory, we have now moved the Student Database applications into a separate virtual machine which has ensured adequate response time and has isolated those users from the effects of other work running simultaneously. This added memory was an unexpected added expense of \$45,000 but it has significantly improved the operation.

Late in the year, we acquired a user-oriented report-generating package called "Easytrieve" at a cost of \$30,000 and, although our experience to date has been brief, the results have been outstanding. Ease of use, functional features not available before, and significant savings in machine resources have been realized, overcoming one of our ongoing problems of providing an "easy to use" method for users to access their data.

Business Systems Development

As of June 1980, there are five major efforts in systems analysis and implementation involving database management methodology. These are our Alumni Records/Gifts/Development System, Budget System, Admissions System, Payroll System, and an interactive addition to our Medical Information System. The Accounts Payable/Purchasing System, under study for feasibility last year, was not recommended for design and implementation because analysis showed the cost/value ratio to be unacceptable. Some consideration is currently under way on this system to redefine the scope.

The Payroll System, acquired some years ago to replace our existing payroll systems, underwent one year of testing in the production environment for the Pension and Exempt Payroll categories. Our experience was unsatisfactory, and effective January 1980, a new development project was undertaken to provide a completely new system using database technology and providing interactive access of employee information to the Payroll Office. This project is administered by a member of the Comptroller's Accounting Office with technical leadership provided by BSD. This is our first system utilizing this project management style and, based on early observations, it provides a better structure for acquiring needed administrative decisions and for resolving conflicts between the various departments involved.

The Alumni System is clearly the furthest along in its development cycle with a scheduled completion date for total turnover planned for July 1981. Admissions, although off to a slow start, is now well on its way to producing a new remote inquiry and update system for the 1981-82 academic year. Schedule completion of this system is September 1981. The Budget System is the most complex because of the number of administrative and academic departments involved in the data gathering, manipulation, and reporting phases. Although some early benefits have been realized with on-line accounting files, for the most part our analysts have spent the bulk of the year defining output documents and reporting modules. In the Medical Area, ADABAS, under a CMS environment, has been utilized to add interactive query capability to what has been for many years a batch, off-line system. This readily available inquiry feature has made a significant impact on the clerical operations of determining insurance coverage and processing claims.

Our learning curve in the database management methodology has been longer and flatter than we had anticipated. Not only has it been a new technique to be adopted by systems analysts and programmers but it also requires a much more integrated environment between user, Operations, Data Control, and System Programming than we had planned. At this time, it is our opinion that we have attained the proper level of DBMS literacy and cross-functional integration. The level of confidence on the part of the analysis and programming staff has increased, and our ability to support the client office as a more unified team has been recognized.

Academic and Research Computing Services

Although many of the activities in serving the front line interface between our users and the computers and software deal with the on-going tasks of consulting, producing documentation, and providing application program maintenance, we have made some significant accomplishments during this past year in the provision of new services as well.

In the area of user/computer interaction, we have been able to physically combine our document room of computer-related monographs, serials and journals, our consulting staff, and our Publications Office, which provides all Center-generated documents to end users. This combined user services facility is located on the second floor of Building 39, providing convenient access to User Accounts, the public time-sharing terminals, the computer output area, and user work areas.

In order to improve our support for statistical and numerical computing, we not only have augmented our staff with part-time, trained statisticians and numerical analysts, but we have established an advisory board on statistical computing comprised of key faculty, staff, and researchers. During the past few years, we have seen an ever-increasing growth in the use of mathematical and statistical packages by the social science community. This group is now emerging as a significant facet of our using community, presenting new demands on our user support staff.

In conjunction with the School of Engineering and based upon a need for an intersession elective course on Fortran, we organized and taught during the Independent Activities Period (IAP) two separate sessions on the subject. The results of this effort were outstanding, with excellent student feedback. As of this date, we are scheduled to repeat these sessions next January. The course provides the prerequisite computer knowledge required in most applications-oriented, follow-on courses now offered within the engineering disciplines.

Although there has always been some demand for IBM's linear programming package MPSX/370 on the campus, the expense in renting such software from the vendor and for providing the necessary technical support has been difficult to justify given the level of usage and its cost. ARCS, working in conjunction with the Operations Research Center and the Center for Computational Research in Economics and Management Science, has completed an equivalent (or better) offering. This software package, known as SESAME/DATAMAT, will be offered to our users this fall. It is possible that this software could be licensed and distributed by MIT to other colleges and universities as a substitute for the IBM product.

With some 130 internal IPS publications and 502 externally acquired documents inventoried and distributed to our users, it was not surprising that some form of computer-assisted management tool was necessary within the Publications Office. Using the Multics Relational Data Management System (RDMS II), we now have both current and historical data for cataloguing, reprinting, pricing, reordering, keyword indexing, and maintaining our document inventory.

During this past year we began a School-by-School audit of computing needs and have completed a detailed study in the School of Science. These studies include personal interviews with key faculty and researchers in each of the departments and are directed toward both current and future computing requirements. The output of this investigation was really twofold. First, we provided to the Dean an overview of what is currently going on in computing within the School, what current needs are not being met, and what the faculty and staff perceive to be future requirements in their disciplines. From IPS's standpoint, knowing what is going on now and knowing what is still desired is extremely valuable in structuring our support effort and in developing new areas of service. From MIT's more global view, input into the total planning process for future computational services is now available to the Dean for discussions with the Provost.

Finally, it is worthwhile at this point to mention another project not yet completed but far enough along so that its benefits will be realized a good nine to ten months before our next report. This project is Multics/MACSYMA. MACSYMA is a symbolic mathematical subsystem created in the Math Lab Project at the Laboratory for Computer Science and implemented on a DEC System 10. Some years ago, an "ad hoc" version was produced for Multics and although it was well received as a needed and highly desirable central service offering, it was incomplete, and in some cases it produced incorrect results. During the past year, ARCS, in conjunction with graduate student assistance and in collaboration with the Math Lab, produced a Multics version which is in the last

stages of "clean-up" and documentation. This service will be a principal Multics offering by mid-fall, not only on the campus, but also over the Telenet, TYMNET and ARPANET interfaces. Access to MACSYMA provided by the Laboratory is severely limited and controlled.

Systems Programming

Somewhat like ARCS, Systems Programming is primarily faced with day-to-day ongoing tasks, keeping up with the latest releases of software operating systems and language processors. In addition, we are engaged in major tasks such as standardizing versions of IBM software between our 370/168, anticipating and designing the correct configuration for our 4331 and follow-on 4341, tuning the main operating system software to improve machine efficiency and terminal response time, and providing the principal technical support for database management and accounting software to provide continuous savings in hardware and machine resources. CMS usage on the 370/168, including administrative database activity, has been recorded as high as 135 simultaneous users. Operating system efficiency has risen and we are now able to deliver as many as 54 seconds of each minute to end-users over CMS.

On the Multics side, we have continued our support to Honeywell Information Systems, providing on-line services to their Cambridge-based systems programming staff and using the MIT facility to test early releases and changes to Multics systems software. During fiscal year 1980 there were 18 major supervisor systems created and installed and more than 300 on-line modifications. In addition, we have begun an MIT project to use Multics as an outgoing gateway processor to the Telenet, CHAOS, and TYMNET networks, using a Digital Equipment Corporation LSI/23. This project should be completed in the fall and was undertaken in collaboration with the Laboratory for Information and Decision Systems.

In June of this year, we celebrated the 10th anniversary of RDMS (Relational Data Management System) on Multics and the release of RDMS II, our latest version. RDMS was developed originally in the Electrical Engineering Department by Professor James Bruce and is used quite heavily by most academic departments within the School of Engineering.

With RDMS II, we expect not only an increase in volume of database usage, but because of its enhancements, a wider usage across the campus. Work has already begun on a query language front-end to RDMS II.

Computer Operations

With the general shift of usage over the past few years, and particularly in 1980, from a predominately batch-oriented user community to one that is almost entirely interactive, significant hardware facility changes have occurred. Output from computer runs, which in years past easily could be controlled with job numbers, is now identified only by user name as the job is submitted on-line by the user from his or her terminal. Because of this, an entirely new method of easily accessible hanging folders available to the users on an open access basis had to be designed and implemented. In addition to facilitating the delivery of output to users, one result was that considerable floor space was released, allowing the expansion of our consulting and user services area referred to in a previous section. With time-sharing being the primary method of access, 24 hour-a-day printing had to be offered in a way that was cost effective. By establishing a remote printer in the Student Center Library maintained by the students themselves, output generated by users at any time may be retrieved, whereas the Dispatch Area at the central facility is closed between midnight and 8 am. Networking also has had a significant impact on computer output, forcing us now to learn to deal with a nationwide community, requiring the packaging and mailing of documents and computer generated printed material.

Further enhancements in printing were achieved by the addition of a Xerox Model 1200 on-line printer to the 370/168 with a Multics interface facility. With this hardware, we were able to reduce our impact printer complement by two IBM Model 1403s, save machine rental dollars, and provide high quality printing on conventional 8½" x 11" sheets at four times the speed we were capable of realizing on the 1403s.

Our user terminal areas were significantly improved during the past year as well by the addition of several high-speed IBM 3270 full-screen devices.

As this report is being written, the most significant hardware change is occurring and that is the installation of our new Model 68 DPS Honeywell Multics processors, memories, and peripherals. This hardware enhancement requires less space and power and is more reliable than our current Model 6180. It should be significantly more responsive to the 100 or so simultaneous users.

The equipment includes two and a half million words of monolithic memory which should significantly increase performance over the current core memory and bulk storage configuration.

WESTON J. BURNER
JOSEPH R. STEINBERG

Undergraduate Research Opportunities Program (UROP)

September 1979 marked 10 years of life for the Undergraduate Research Opportunities Program (UROP), and the beginning of its second decade. During these years, UROP has fostered and supported the pooling of talents by students and faculty to work together on research projects of mutual interest in nearly every field and department and nearly every laboratory at MIT. An attendant atmosphere of excitement, anticipation, and satisfaction derives from the contributions of the young researchers to the overall research program at MIT, and the mutual personal benefits enjoyed by the researchers themselves, students and faculty alike.

Student Research Opportunities Directory, the UROP annual publication, distributed since 1969, continues to be our most important publication. It has become a primary resource for the MIT community, prospective students, and prospective research sponsors, with its extensive listing of faculty research interests, funding sources, and Institute programs.

This anniversary year was noted in some special and some lighthearted ways. An exhibit in the Compton Gallery displayed highlights of UROP's birth and growth, placing it in historical perspective as part of the story of Building 20. UROP sold T-shirts to the MIT community in the spring commemorating "UROP -- Ten Years." The proceeds were used to host an outdoor UROP birthday party on May 14, open to all.

Modes of participation encouraged by the program were as varied as they have ever been. The majority of the estimated 2,500 student participants this past academic year elected to do undergraduate research for credit. As has happened every year in UROP, a significant number of students elect to receive neither credit nor pay for their efforts. Of those students who did receive a term-time research stipend, about half will continue with their research full-time for the summer of 1980. UROP continues to solicit evaluations at the end of every semester and summer from both faculty member supervisors and UROP students, and off-campus supervisors. We carefully review and follow up on these evaluations where necessary or appropriate. Site visits to selected student investigations also play an important role in keeping abreast of student-faculty interactions, research progress, contents, and problems. The evaluation and site visit activities, together with student proposal activities, are the continuing bases of UROP's personal interactions with faculty and student participants and, more often than not, are the sources of program policy and philosophy.

Joint concerns and joint undertakings have continued to create close interaction with many offices and programs throughout the Institute. We work or coordinate with the Student Employment Office, the Arts Council, the Industrial Liaison Program, the Health Sciences and Technology Program, the Urban Studies and Political Science departments' Public Policy Program, the Office of Sponsored Programs, Sea Grant, and others. Recent discussions with Sea Grant have led to the establishment of a Sea Grant Undergraduate Research Award to be given during the next academic year. Concern for student liability, safety, and patent protection keeps us in frequent contact with the Patent Office, the Committee on the Use of Humans as Experimental Subjects, and MIT's Insurance and

Legal Administration Officer. We attempt to be aware, to as great an extent as possible, of Institute trends, departmental and laboratory priorities, and student needs, breaking new ground in setting Institute policy when the need arises.

The cost of research has escalated enormously in the past decade. Since, in real dollars, UROP's budget has remained approximately constant during the past five or six years, the effective "buying power" of UROP has been significantly eroded by inflation. To mediate this potentially pernicious economic influence, UROP has emphasized "research initiation" support for many students as opposed to long-term, continuing support for a few. Flexibility in fiscal arrangements has helped to set a tone of cooperation and goodwill among participants, such that UROP's financial support of undergraduate research stretches far beyond UROP'S own budgeting capabilities. For example, UROP may help a student begin to carry out his or her own idea with initial financial support for materials, or might share the first round of wage support with a faculty supervisor's sponsored research funds. Once research is well under way, UROP then urges the faculty member to underwrite full support, and on the basis of student-submitted proposals, may rule indirect costs inappropriate to the student stipend. Last summer UROP students received nearly \$.5 million from faculty supervisors, levered by less than \$170,000 from UROP's own budget.

Increased tuition costs, general inflation, and the resulting financial pressure felt by students led us to increase our hourly rate and total stipend as we went into the summer of 1980, a move anticipated over a year ago. This increase raised the UROP hourly rate from \$3.50 an hour to \$4.50 an hour. Early evidence suggests that this decision has enabled students who might otherwise have had to seek summer work elsewhere to elect instead the continuation of their research here at MIT. Although UROP student wages have increased three times since our 1972 hourly rate of \$2.50, they still fall short against the realities of inflation and climbing education expenses.

Besides faculty-contributed monies from sponsored research grants and Institute general funds, financial support for undergraduate research through UROP also comes from a number of outside sources. A grant from Dr. Edwin Land of Polaroid Corporation, given to the Eloranta Summer Fellowship Program, awarded summer stipends and money for materials to five students involved in research of special distinction. One student majoring in biology was awarded a stipend for a project in southern writing; one for working on a study of Nantucket scallops; one conducted geological research in subarctic Norway; another studied the mechanism of New England's "red tides"; and the fifth was involved in a nutrition study. The Clapp and Poliak fund offers awards for work in engineering design. It supported one student who adapted a bicycle for paraplegics, and another student who presented a paper on his electrical engineering research at a conference in California. The Mining and Minerals Resources Research Institute resulted in fall-term support for six students, spring-term support for seven, and summer stipends for four students. The Society for Sigma Xi offers financial support to students for equipment, supplies, and travel. Money was provided for materials for five students this year, one of whom was also aided to attend and present a paper in place of his faculty supervisor at a limnology conference in Kenya. The Uniroyal Foundation staked two beginners in research, with monies earmarked for that purpose. Two Wellesley students involved in UROP projects were offered modest stipend support from Wellesley College. MIT alumni directly aided UROP research through the Class of 1970 Research Awards, this year supporting a student doing research on the hazards of low-level radiation.

Having "come of age" in these 10 years of growing MIT commitment to undergraduate research, UROP has many alumni, who began UROP as freshmen and are now themselves UROP supervisors, or newly established professionals. Whether it be these UROP alumni who have spread the news about UROP, or whether information has spread from articles about UROP which appear with some frequency, or whether it has been pre-freshman inquiries, UROP has been brought to the attention of alumni groups throughout the country and this has resulted in continual UROP-alumni interaction. This fall the MIT Club of Northern New Jersey invited two students to speak at one of their monthly gatherings to alumni, future MIT students, and parents. UROP staff members were invited to address meetings of the Boston, Detroit, Minneapolis, and London MIT clubs. In turn, an alumnus was invited by UROP to be a guest speaker at a UROP-sponsored Independent Activities Period symposium. UROP staff members also addressed high school students in Darien, Connecticut, and Canton, Massachusetts.

To help prepare students to be professionals and acquaint the MIT community with the work UROP researchers do, UROP sponsors symposia during the term to provide students a forum for their ideas. This year the UROP student symposium was called "Undergraduate Research in Energy

Production and Energy Policy." The Industrial Liaison Program joined forces with UROP in the spring term to present a daylong symposium entitled "MIT and Industry: Joint Educational Ventures." Three students formally discussed their work in three different areas: polymers in sustained drug release, solar cells, and human productivity in space.

In an effort to expose more students to research in general, as well as to research done by undergraduates, UROP has offered term-time undergraduate seminars which link undergraduate research to current issues. In 1978 and 1979 the seminar was concerned with energy policy issues. The 1979 seminar dealt with medical policy issues. The format of the seminars takes maximum advantage of the willingness of MIT faculty member supervisors, UROP students, and Boston-area off-campus professionals to share their concerns and talk about their enterprises.

This year saw physical changes for UROP headquarters. After about seven years in more or less the same quarters in Building 20, our offices were renovated, requiring a temporary move, followed a month later by our return to the newly refurbished Room 141. Besides providing UROP staff with the room to function more efficiently, our office now provides students with a small area for perusing information. Two new people joined UROP this year: Susan Mitchell-Hardt replaced Charles Edmundson, who moved to the Development Office; and Michelle Lamarre joined UROP in January on a part-time basis. They join Professor Margaret MacVicar, UROP Director; Norma McGavern, Associate Director; Clifford Truesdell, Assistant Director; and Gregory Smith, Special Projects Volunteer.

The change in MIT governance structure beginning July 1, 1980, will alter UROP's intellectual home from the Office of the President and Chancellor to the Office of the Provost, as was true in the days of UROP's beginning. In between, UROP has looked for administrative support to the Education Development Center, then to the Office of Vice President for Research, and more recently, to the Office of the Vice President.

As we reflect on the years past and read articles such as "The MIT Educational Explorers Club" or "Teaching Students to be Independent of Formal Education" (*Technology Review*, October 1979) the *Review* article about the large UROP group in the Space Systems Laboratory studying human productivity in space, or the references to UROP which appeared in a June 1980 issue of the *New York Times Magazine*, it is clearly evident what a significant role undergraduate student participation in research has played in the growth and change in life at MIT. We look forward to the next 10 years, especially to participating in the evolution of the MIT academic program in directions which build on the foundation UROP has helped to lay.

NORMA MCGAVERN
MARGARET MACVICAR

Vice President, Financial Operations

The financial operating results for the year show the Institute to be essentially in balance between income and expenses for the fourth year in a row. The present budget estimate for the fiscal year 1981 shows an unfavorable imbalance of approximately \$1 million, but with hard work and some good fortune it's quite likely that the year will end once again in approximate balance. If present trends continue, the Institute's total operations will cross the one-half billion mark within the next two years. While this is a very large sum of money, the bulk of it is made up of current annual funding, and our concern continues to be the capital base of MIT which is not growing at the same rate nor is it able to keep up with the erosion caused by high inflation rates. Nevertheless, the vitality of the Institute stays strong and healthy. Applications for admission at the graduate and undergraduate levels reflect the high standing of MIT in the nation and the world. Sponsored research activities continue to grow at a rapid rate as the country turns to science and technology to restore our economic position in the world and to maintain our position of leadership across the board. The problem of the next few years will be one of selectively limiting our activities to those which can be supported from the available resources.

The Federal Office of Management and Budget (OMB) issued in February 1979 its revision to Circular A-21, which states the cost principles under which colleges and universities are reimbursed for their sponsored research expenses. The revised circular takes effect at MIT on July 1, 1980. Thus, during the fiscal year 1980 a great deal of effort went into analyzing the new document and providing for its implementation. It appears, after all is said and done, that there is no major financial impact one way or the other as a result of the revisions, and MIT's financial and administrative systems continue to be accepted by its cognizant Federal agency, the Office of Naval Research. The one major change which will have to be reflected is that the base upon which indirect costs are collected will change from one of salaries and wages (plus employee benefits) to one called Modified Total Direct Costs. This change in base will be felt more by the funding agencies than by MIT projects. There could have been a financial impact on MIT because of this change had we been required to implement immediately since the present funding on hand and the funding requested by outstanding proposals have been planned with salaries and wages as the base. By delaying the effective date of this requirement to July 1, 1982, the Office of Naval Research is permitting MIT to seek funds on the new base with sufficient advance notice to the sponsors. This should help us through the transition without the severe impact that might otherwise have been felt.

A separate effort, but one which had been coupled with the Circular A-21 negotiations, is the request of the college and university community to the Federal Office of Management and Budget for the allowability of interest costs and for an allowance for independent research and development. OMB is now in the process of studying both of these requests, and MIT, led by President Wiesner, has had a direct hand in presenting the university case both directly to OMB and indirectly through the Washington-based organizations. The prospect for the allowability of interest, at least as it relates to new building costs, appears to be quite good. The chances of getting some provision for independent research and development, sometimes known as intellectual capital formation, also appears reasonably good, provided the decision is made at the very senior levels of the Federal government.

We should also recognize two other favorable developments in the year 1980. One is that the National Science Foundation (NSF) has now agreed to accept cost sharing on an Institute-wide basis, rather than project by project, and this is of great significance to MIT as it reduces the demand for unrestricted funds to participate in that cost sharing. Secondly, the OMB is favorably disposed to the NSF view of cost sharing and is seeking to provide for this broader concept in the new legislation which comes out of Congress. We are encouraged by what we see as the continuing betterment in the overall Federal-university relationship despite occasional outcries, which tend

to distort the view of that relationship. In other words, if you look at the forest and not the trees we believe the partnership is in a much healthier state today than it was two or three years ago.

For a more detailed report on financial operations, please refer to the Report of the Treasurer for the Year Ended June 30, 1980, which is reproduced in this document.

STUART H. COWEN

Office of the Comptroller

During fiscal year 1980, a major effort continued toward the completion of a new integrated payroll system. A team comprised of Comptroller's Accounting Office staff and Business Systems Development staff members was assigned the responsibility for developing and implementing the Gross Pay to Net Pay process (including time input). Completion is expected for spring 1981.

New funding provided by the government to cover the cost of Lincoln Laboratory operations during fiscal year 1980 totaled \$141.7 million. The Department of Defense continues to be the principal support for the Laboratory, furnishing 88.3 percent of the total. Other funds were provided by the Department of Transportation (3.9 percent) and the Department of Energy (6.3 percent). The balance of the support was received from the National Science Foundation and the National Aeronautics and Space Administration.

In support of the Laboratory's performance of this volume of research, the Lincoln Laboratory Fiscal Office has initiated during the year the development of an integration of its automated accounting systems, with a goal of providing a data base for an information system of value to the management. It is anticipated that the system will be in place with the start of the Laboratory's contract year, October 1, 1980.

Personnel Changes

There were several staff changes during the past year. In August 1979 Guy L. Spina was promoted to Senior Staff Accountant. In October 1979 Carolyn H. Brooke was promoted to Staff Accountant, Carole E. Nassif was promoted to Staff Accountant, Mitchell A. Kloza was promoted to Senior Accounting Officer, and David E. Burnett was promoted to Senior Staff Accountant. In December 1979 James B. Enos was promoted to Senior Accounting Officer, Ruth E. Walsh was promoted to Accounting Officer, Roberta F. Burns was promoted to Accounting Officer for Sponsored Accounts, Robert J. Long was promoted to Accounting Officer for Sponsored Accounts, Doris M. Marzioni was promoted to Senior Staff Accountant, Kathleen M. Lalor was promoted to Senior Staff Accountant, Mary Ann J. Donofrio was promoted to Senior Staff Accountant, Alan E. Harrington was promoted to Assistant Accounting Officer, William J. Duggan joined the Comptroller's Office in the capacity of Assistant Comptroller, and John P. Donahue returned to the Institute in the capacity of Associate Comptroller, subsequently succeeding Robert V. Dodd who retired after directing the Lincoln Laboratory Fiscal Office for 28 years. Mr. Dodd, Associate Comptroller, retired June 30, 1980. In January 1980 Carl A. Seagren was promoted to Senior Staff Accountant.

PHILIP J. KEOHAN

Office of Sponsored Programs

For fiscal year 1980, the total volume of sponsored research performed on campus is expected to approximate \$163,122,000, an increase of 15.4 percent over fiscal 1979 volume of \$141,306,000.

As shown in the tabulation which follows, on-campus research supported by the Departments of Defense and Energy continues to reflect substantial growth, while the most dramatic gain is in research supported by industry, which has nearly doubled in the last two years.

CAMPUS RESEARCH VOLUME BY SPONSOR
(In thousands of dollars)

	<u>1967</u>	<u>1977</u>	<u>1978</u>	<u>1979</u>	<u>1980</u>
Department of Defense	17,477	11,678	13,694	15,223	19,183
Department of Energy	8,089	20,943	32,338	42,005	50,004
Department of Health and Human Services (formerly DHEW)	6,411	19,140	18,855	22,061	25,320
National Aeronautics and Space Administration	6,267	7,997	8,064	9,505	9,295
National Science Foundation	5,508	21,469	21,832	23,469	25,055
Other Federal Sponsors	1,548	6,313	7,363	8,727	9,554
<u>Total Federal Sponsorship</u>	<u>45,300</u>	<u>87,540</u>	<u>102,146</u>	<u>120,990</u>	<u>138,411</u>
Industry	2,045	5,957	6,745	8,151	13,058
Foundations and Other Nonprofits	2,606	7,674	7,917	9,538	9,654
Other	646	2,907	2,466	2,627	1,999
<u>Total Non-Federal</u>	<u>5,297</u>	<u>16,538</u>	<u>17,128</u>	<u>20,316</u>	<u>24,711</u>
<u>Total Research Volume</u>	<u>50,597</u>	<u>104,078</u>	<u>119,274</u>	<u>141,306</u>	<u>163,122</u>

New Programs and Facilities

The formation of the Materials Processing Center within the School of Engineering was announced in August. The Center will provide a way for the staff and faculty of the School of Engineering, and others, to contribute effectively to broad materials processing problems and to interact with industry and government in finding solutions to these problems. The Center will contribute to the educational goals of the Institute through development of new curricula, seminars, and continuing education programs. It will also encourage the extended residence at MIT of industry and government personnel as visiting faculty, adjunct faculty, and postdoctoral researchers.

In November, the National Endowment for the Arts awarded MIT a challenge grant of \$250,000 toward new facilities being designed for MIT's research, teaching, and exhibition programs in the arts and in media technology, to be located on MIT's developing east campus. The first phase will consist of exhibition and archive spaces for works by contemporary artists and architects; teaching

Vice President, Financial Operations

and production facilities for film, video, and holography; and work spaces for resident artists. Later phases will house specialized laboratories, studios, workshops, and teaching spaces.

In October, MIT received a \$1,527,000 grant from the National Science Foundation (NSF) to establish a regional center for use of advanced laser systems in basic research on atoms and molecules. The facility, to be known as the Northeast Regional Center for Laser Spectroscopy and Dynamics, will make powerful new scientific techniques and instruments available to a broad community of university and industrial scientists in the New England and Mid-Atlantic states. The Northeast Center is one of eight centers funded recently by NSF to improve the quality and scope of US research, by making sophisticated instruments widely available and by taking advantage of the economics of sharing such instruments.

MIT announced in January plans to establish a \$5 million integrated-circuit fabrication facility on the campus. The facility will be the centerpiece of a major education and research program that MIT has mounted in response to the design and miniaturization crises that threaten to slow down the advancement of the technology of very large scale integrated (VLSI) systems. The new program encompasses four areas -- submicrometer structures technology, semiconductor materials and devices, integrated-circuit design automation, and integrated system architecture. In addition, the facility will assist in a new activity in artificial intelligence, aimed at understanding, and eventually automating, the human design process in the context of integrated-system design.

MIT and Exxon Research and Engineering Company (ER&E) jointly announced in April that they have entered into a 10-year sponsored research agreement in the field of combustion science. The agreement is one of the largest and longest in duration of its kind between a university and a corporation. Under its terms, the Exxon affiliate could provide MIT with between \$7 million and \$8 million for research support over the life of the agreement. One of the major objectives of the program will be to help generate the scientific base for more efficient and more environmentally acceptable burning of high sulfur, high nitrogen, and hydrogen-deficient fossil fuels like coal, coal liquids, shale oil, and heavy crude oil.

Personnel Changes

During the year the following staff changes occurred in the Office of Sponsored Programs: effective September 1, 1979, Paul H. Quinn was promoted to Associate Director, Grants and Administration; David J. Harrigan to Associate Director, Contracts; and Carol Van Aken to Special Projects Director.

As of January 1, 1980, Joseph F. Connolly, Thomas B. Duff, Paul C. Powell, and George F. Prendergast were promoted to the position of Coordinator.

On August 1, 1979, Donna M. T. Herlehy, Assistant Director, transferred to the Laboratory of Architecture and Planning as Administrative Officer; and on October 8, 1979, Rosanne Kumins, formerly a Negotiator in the Office for Research Contracts at Harvard University, joined OSP as Assistant Director.

On November 30, 1979, Mary Louise Atkinson left MIT to take a position at the GCA Corporation in Bedford.

GEORGE H. DUMMER

Office of the Director of Finance

As we planned for fiscal year 1980 in the months of January through March 1979, we anticipated an inflation rate of about 6 percent, and it was on this assumption that salary and tuition increases were based. From the time budget decisions were made until the start of the year on July 1, inflation accelerated rapidly and we entered the year at a 13 percent annual rate with the cost of energy leading the way.

Energy costs so dominated the summer months that we were forced to increase the budget in September by \$2,200,000 for energy alone. Again in November a further increase of \$890,000 was required, bringing the Institute's gross energy budget to \$10,150,000, a 43 percent increase from the original 1980 budget.

As the year progressed it became apparent that two events would work in our favor despite the effects of inflation on the operating budget. First, a relatively snowless winter produced savings as the Institute did not have to be closed because of inclement weather.

Second, the Federal Reserve Board began to tighten up on the availability of money by increasing the discount rate it charges member banks. This had the effect of sharply driving up the prime rate banks charge their best customers. Several such actions on the part of the Federal Reserve during the winter months resulted in a prime rate of almost 20 percent in February. The short-term money market reacted to these moves, and as a result, MIT's investment income did substantially better than anticipated a year earlier.

While the financial results for the year are not known exactly as this report is written, it is anticipated that the year will close in financial equilibrium.

As we planned for fiscal 1981, it became clear that the effect of inflation could not be denied and that substantial increases in budgets for salaries and expenses would be required. The 1981 tuition rate (which is decided six months before the fiscal year begins on July 1, 1980) was increased by 17 percent to \$6,200, the largest increase in our history. Of this increase it is hoped that 12 percent will cover the anticipated inflation in fiscal 1981 and 5 percent will help to cover the fiscal 1980 inflation which was underestimated when this year's tuition was set.

In May the Institute completed the financing of three large facilities currently under construction: the Athletics and Special Events Center, the Health Sciences and Health Services Building, and a new undergraduate dormitory. The financing, totaling \$38 million, was accomplished through the Massachusetts Health and Educational Facilities Authority which is authorized to sell tax-exempt bonds on behalf of private non-profit health and educational institutions. This is MIT's fourth, and largest, borrowing through the Authority. Again, to underscore the financial climate of fiscal 1980, at the time the Executive Committee of the Corporation approved the bond issue on April 4, the anticipated net interest cost was 9.25 percent. From this time until the bonds were sold by public bids on May 14, the tax-exempt market rates took a precipitous (but fortuitous for MIT) plunge and the sale was made at a net interest cost of 7.26 percent.

This past March the Institute signed two 3 percent mortgage notes, for a total of \$1,247,000, with the Department of Housing and Urban Development under the College Housing Loan Program. The financing supported major renovations on one student housing project and energy-related renovations on another. Both projects have helped to alleviate the current shortage of student housing.

The offices of the Director of Finance and Business Systems Development (BSD) are continuing with the budget and management information system project. The Chart of Accounts was made available for test and user analysis under the data base management system, ADABAS. Newly designed financial analysis reports for various managerial levels are being presented for discussion with administrative officers. In addition, two management information systems are being investigated to assess their adaptability to the Institute structure.

Student Accounts Office

The Student Accounts Receivable Office had billings for the year in excess of \$55 million for tuition, dining, dormitory, student insurance, and other miscellaneous fees. Joanne Barrett replaced Karen Goode in October as the Student Account Representative for graduate students enrolled in the School of Engineering. Ann Chick, Student Account Representative for juniors and seniors, was promoted to Senior Staff Accountant.

Student Loan Office

Student loan notes receivable outstanding were \$29.8 million at the close of the fiscal year, an increase of six percent over the previous year. These notes are funded by \$8,492,000 of MIT loan

funds established by friends and alumni of the Institute; \$15,012,000 of Federal funds in support of the National Direct Student Loan program (NDSL); \$446,000 in funds borrowed from the Federal government to support our contribution to the NDSL program; \$2,000,000 borrowed from the Student Loan Marketing Association; and \$3,850,000 from a local bank. Our total borrowings to support student loans increased by \$54,000.

It is interesting to note that \$21 million or 70 percent of our student loan notes receivable are through the Federal NDSL program and the MIT Federal Insured Loan program. Fifteen years ago our total student loan notes receivable was \$6.9 million, with just 23.5 percent in Federal program loans. During these past 15 years we have issued \$45.5 million in student loan notes with 60 percent from Federal programs.

JOHN A. CURRIE

Audit Division

In the calendar year 1979 the Audit Division engaged in its continuing task of verifying that management policy and procedure were being properly implemented, that internal controls were being maintained, and that assets were safeguarded. These tasks were met by audits of departments and functions through tests and evaluation, ascertaining that the units reviewed are operating effectively according to Institute guidelines and within prescribed contractual and budgetary limitations; audits of administrative units verify that internal control of procedures and authority is evident; and audits of inventories, receivables, and cash (or equivalents) validate the control and authorized use of Institute assets and also determine valuations for annual statement presentation.

For the most part, procedures and controls are administered effectively and Institute policy is maintained. Our suggestions are given serious attention and noted weaknesses are promptly adjusted. There is a serious concern for budget limitations, which is demonstrated by the attention and interest given in seminars and courses offered to the departments by cognizant Institute units, and to the increasing use of computers in the management of accounts.

Special projects develop from items noted in regular audit work or from requests for assistance or information as in the following instance: at the request of the Vice President for Research and the Director of the Nuclear Reactor Laboratory, the Audit Division conducted a review of the accountability reports for radioactive material within the laboratory. Our purpose was to determine the procedures, scheduling and reporting of inventories of this material, and assure that the reports and related work sheets were available in various locations, in the event that a reconstruction of data was required. The features of security and safety were addressed by other groups appointed by the Vice President for Research. In addition to reviewing the accountability, the Audit Division participated in the most recent inventory of the material at the laboratory. We found the accountability and the methods used to be most thorough, complete, and responsible.

In the current year, the EDP Audit Section concentrated its efforts on currently operating systems, notably in Purchasing and Accounts Payable areas. Also an operational audit of Tape/Disk Library Controls was completed to obtain assurance of historical and functional availability of data. Recently installed systems were tested for reliability and completeness; and participation in systems feasibility, development, and management services continued.

The Audit Division allows for consultation with supervisors on items of business procedures on specific questions or problems that may arise. We encourage these contacts with administrative officers and assistants as a means of service and also to maintain an awareness of current problems or changes of concern to departments.

Audit Division

During the year, auditors attended meetings of the local chapters of the Institute of Internal Auditors, the EDP Auditors Association, and the Massachusetts Society of CPAs. Two auditors are active as a director and seminar participant in the EDP Auditors Association. Auditors are attending seminars at MIT, taking courses at other colleges for advanced degrees, and have attended seminars offered by companies and professional groups on subjects related to auditing and systems analysis.

EDWARD L. MCCORMACK

Vice President, Operations

The past year witnessed the intensification of two of the major elements in our recent physical preoccupations. Building plans have become construction realities, and the energy problem has taken on more severity and has brought forth more creative efforts to cope with it. These matters are described in some detail in the reports that follow.

It has been a year of reawakened building activity. Several parts of the campus are changing in appearance weekly before our eyes and give an idea of the important new facilities and vistas we will enjoy. Not evident to the eye, however, are equally important activities taking place in the unrelenting battle to cope with the new era in energy. Significant changes in our building systems are being put in place, new tools for controlling them are being installed, and alternate fuel sources are being weighed and negotiated for. It is a time which has called for and is receiving a first-class effort.

Plans for implementing the recommendations of the Committee on Campus Dining have occupied the time of many during this past year. It has involved faculty, staff, and students alike. A carefully thought out plan providing for flexibility and physical improvement in the dining experience at the Institute has been announced and will start at the beginning of the next academic year.

As the Institute continues to move into new fields and new frontiers, the matter of the safe conduct of our work and the protection of our people calls for continual vigilance, education, and more comprehensive safety activity. Some of these new dimensions are touched upon in the report of the Safety Office. It is gratifying to note that the Massachusetts Safety Council Judging Committee for the 1979 Occupational Safety Award Program has named MIT the Group Winner for Large Organizations in the Educational Service category.

Significant organizational changes have been made in the Office of Purchasing and Stores during the year. They represent attempts to simplify and consolidate the Institute's purchasing activities. In addition, procedures and systems are undergoing review and modification where deemed advisable and necessary for efficiency and for compliance with changing Federal regulations. New and significant requirements, with respect to purchasing and subcontracting from small disadvantaged and women-owned business concerns, call for new accounting and reporting procedures and a reinforced effort in this area.

This will be my final report as part of the *Report of the President and the Chancellor*. I leave my post with the secure knowledge of the extraordinary skill and devotion of my successor and of the able and conscientious group of department heads whose reports follow.

PHILIP A. STODDARD

Physical Plant Department

Utilities

The energy conservation activities of the plant continue to be effective in reducing the Institute's utility bills. Modification of operating schedules, better control of devices, and increasingly efficient use of the central computerized Facilities Control System resulted in a further one-year drop of almost 10 percent in our fuel consumption. We currently stand at an overall reduction of 42 percent relative to our pre-emergency (1973) fuel consumption level.

Our Building Energy Audit and Modification (BEAM) program, initiated during fiscal year 1979, reached the construction level during this year. Audits, followed by design for substantial modification to the heating, ventilating, and air conditioning mechanical systems in several of our most energy-intensive buildings, have been completed and construction will be starting this fall.

Incentive for energy conservation continues at a high level, reflecting the continued escalation of fuel prices, both in fuel oil and our alternate fuel, natural gas. We experienced a dramatic increase in fuel oil prices during fiscal year 1979, with oil increasing by 60 percent. Fiscal year 1980 was even worse as the price escalation continued unabated and fuel oil moved up from the summer level of \$22/Bbl to \$32/Bbl by mid-winter.

A moderating factor on the total cost impact of fuel escalation has been the availability of somewhat lower priced interruptible natural gas during the heating season, in addition to the normal use in the summer and transitional seasons. In the winter of fiscal year 1980 we were able to obtain a special block purchase contract for interruptible gas which met most of our needs during the very cold demand months.

Environmental control regulations of all types continue to be felt in the daily activities of physical plant. Under the requirements of the Clean Water Act of 1977*, the Metropolitan District Commission (MDC) has established rules and regulations covering all discharge of sewage and waste by industrial users in the district. Large institutions are classified as industrial users under Federal and State regulations, and MIT, as a very large water user, was extensively audited by MDC engineers during the year. The Institute was found to comply with current regulations and was granted building permits for sewage discharge. The Institute's high use of domestic water (currently almost 10 percent of the supply to the City of Cambridge) will come under increasing scrutiny as both sewer disposal and supply problems gain public attention. MIT will have to be more prudent in its use of this valuable and costly resource, and the wasteful use of water for process is now being discouraged as campus-wide applications come under review.

During the year, a master's candidate in the Department of Ocean Engineering completed a thesis study, "Investigation of the Utilization of Coal at the MIT Central Utilities Plant." This study was a careful and thorough extension of earlier cogeneration studies also under the direction of Professor Douglas Carmichael. The report indicates that coal firing is a viable alternative for MIT in Cambridge, and that it is actually the economical choice under present Federal energy regulations. These studies will play a substantial role in shaping our planning as we face the necessity for additional boiler capacity in the mid-80s.

*Federal Water Pollution Control Act Amendments of 1972

Architecture, Engineering, and Construction

The construction and renovation activity increased substantially during the fiscal year with four new projects being initiated: renovation of the former Webster Building on Amherst Street (100,000 gross square feet), scheduled for completion in April 1981; the new Whitaker Health Sciences, Technology, and Management/Health Services complex (250,000 gsf) on the east campus, scheduled for completion in the fall of 1981; and Next House, a new West Campus undergraduate dormitory (125,000 gsf) on Memorial Drive, also scheduled for completion in the fall of 1981.

Work continued on the Athletic Facility, a two-story brick-faced structure with an ice rink below and a field house on the second floor. When this facility is completed in the fall, it will provide the first indoor skating facility at MIT. The major animal facility renovation on the sixth floor of the Ford Building was active throughout the year and is scheduled for completion in July of 1980. The renovation of the Whitaker Building 8th floor animal facility was completed last summer. The completion of these two projects, along with the new Interim Animal Facility on Vassar Street occupied in 1978, marks the culmination of a major effort to bring our research animal handling areas into conformity with current governmental regulatory requirements.

After more than a year of study and investigation, a major roof renovation was scheduled for Kresge Auditorium in the spring and summer of 1980. The old roof had been a continuing problem almost since the auditorium opened 25 years ago. In preparation for replacing the roofing system last fall it was discovered that the deterioration of the concrete at the buttress points had progressed much further than anticipated. As a precaution, the building was closed and remedial work began immediately. Alternate arrangements were made for the events and meetings scheduled in Kresge Auditorium including the use of Jordan Hall in Boston, the Loeb Drama Center at Harvard, and a number of MIT lecture halls. The concrete repair work was completed this year and new waterproofing, insulation, and wood decking installed. The installation of the new copper roofing surface has started, with completion scheduled for early fall 1980.

Building Operations/Support Services

The Institute revised its space temperature guidelines to comply with the President's Federal Emergency Building Temperature Restrictions of 65 degrees maximum in winter and 78 degrees minimum in summer. The dormitories were excluded and a number of buildings were exempted because they contained research activities.

During the year decisions were made to go forward with a new solid-state equipment expansion of the Autocall System (fire alarm and emergency) and a microprocessor-driven extension of the Facilities Control System (building control and energy-use monitoring). Both these systems will serve the latest generation of new buildings on the campus.

Telecommunications

The program in the Telecommunications Office of installing interconnected or non-telephone company provided systems and equipment in selected areas continued in fiscal year 1980. Included in this program was the installation of a new multifeatured key telephone system in the Industrial Liaison Program Offices.

A study of telecommunications at MIT was made by Arthur D. Little, Inc. with the major objective of giving MIT the benefits of an independent review of the state of telecommunications at the Institute as an aid to further planning over the course of the next five to ten years. The study provided a useful timetable and outline of constructive changes for the Institute's systems. We will continue to evaluate the report's recommendations in the light of evolving telephone company rate structures, new technology, and changing Institute requirements.

WILLIAM R. DICKSON

Planning Office

This year, the Planning Office has been engaged in:

- A review of MIT's long-range growth and change
- The preparation of development plans for several academic departments and schools
- The implementation of student housing plans and related parking facilities
- Plans to improve the Institute's physical environment through additional landscape planning
- Transportation and traffic planning for the campus and environs
- Community development projects in Cambridge that will have a long-term impact on the character and development of the MIT community

In anticipation of a change in administration, the completion of the Leadership Campaign, and the normal decennial review of the development of the Institute, a review of MIT's growth and change over the last 40 years was undertaken. This review will serve as a reference as the Institute reviews the major planning issues that it will face during the 1980s.

Plans for Departments and Schools

Planning studies for the Sloan School's expansion were completed this year. The plan proposed that the School's teaching facilities be concentrated in a renovated 70 Memorial Drive. This will then free up space in the Sloan Building and will permit a phased renovation of the building and an expansion of its programs. Simultaneously, expansion of the Endicott House facilities to accommodate growth in the senior executive program will be undertaken.

The plan for installing the Program in Science, Technology, and Society in newly renovated space at 70 Memorial Drive was completed and approved this year. This program, together with the teaching facilities being developed for the Sloan School in the upper levels of this building, will complete the occupancy of 70 Memorial Drive.

During this year provision for the expansion of the Brain Sciences Program was made through the addition of a sixth floor to the proposed Health Sciences Building. Planning is now under way for new facilities for the Psychology Department and Brain Sciences programs in an area immediately adjacent to the Health Sciences Building.

Planning continues for the Arts and Media facility to be located on Ames Street on a site now occupied by two industrial buildings.

A parking and circulation plan for the East Campus was completed this year and is being implemented in connection with the new building projects under way in the East Campus. Furthermore, we have continued to work with the MBTA and the Cambridge Redevelopment Authority on the location and development of the new Kendall Square Station. This station will be substantially more convenient for rapid transit service for MIT's population.

A landscape development plan for the East Campus has been proposed. We hope that its implementation will be accomplished in association with new building projects in the East Campus.

Several land acquisitions and land transfers have been completed in this part of the campus in order to ensure MIT's ability to meet the parking requirements in the East Campus in the most economical manner.

On the Main Campus the facilities plan for the Physics Department has been completed and transmitted to the Provost. The implementation of this plan is a key to the future of the School of Science's space needs, and we expect it will be addressed in the near future.

The Department of Electrical Engineering and Computer Science has proposed a major new facility for integrated circuit design and manufacture. Planning has moved forward to identify alternate sites and development opportunities to accommodate this major new program. Also, a proposal to build an addition to house a common room and lecture facilities for the department is being explored.

The School of Architecture has been implementing its general plan for the development of a Center for Islamic Architecture Studies, and is planning for the relocation of a number of its arts and media activities to the nearby N51 Building on Massachusetts Avenue.

The Plasma Fusion Laboratory has continued to grow as scheduled and now occupies space on Albany Street.

Landscape and Environment

Continued planning for the improvement of the Institute's environment through the expansion of landscape projects and related services continues. The competition for every foot of ground will make this task more difficult in the future, but nonetheless essential.

Transportation Planning

Parking plans for the East Campus, West Campus, and Main Campus were prepared this year and are under review at this time. A computerized information system on parking resources and permits has been initiated and will be of great assistance in developing policies and procedures in the years ahead.

Bicycles are becoming more important on this campus, and additional cycle storage facilities and cycle ways are being studied.

Ride sharing is on the rise as a result of a greater sensitivity to the cost of fuel, and more recently to the increase in the cost of public transportation.

The Handicapped Access Program was reviewed this year and will be implemented over three years. This program will provide for the elimination of a number of key barriers to handicapped access to MIT's main buildings.

Student Life and Housing

The Next House, the last of the undergraduate houses to be built on sites along the river, provided in the 1960 Plan for Undergraduate Housing, is now under construction. This project stimulated a major relocation of student resident parking and will undoubtedly have an impact on athletic facilities when the 400 plus new residents are in place in the fall of 1981.

Planning efforts have been under way all year to identify sites for the development of additional graduate housing. These efforts have been constrained by the growing competition for land and a lack of financial resources for graduate housing.

Community Planning

The Kendall Square Urban Renewal Project began this year with its first commercial project, a 13-story office building now under way.

Planning continues on the former Simplex properties. The City of Cambridge has now undertaken a major planning study in which the Planning Office and other MIT offices are involved.

Pressures on the city's tax resources are reflecting themselves in a review by the city of institutional land ownership and tax payments. The Planning Office has recently completed a study of the Institute's land purchases and tax payments over the last 10 years.

The activities of the Planning Office this year suggest it is vital that the Institute undertake a review of our planning assumptions and goals for the next 10 years. The need to have policies to guide land use and development is essential. The development of procedures and priorities is the key to ensuring that the Institute can provide an appropriate physical environment for its academic and related programs in the future.

In an era of public suspicion of institutions, it is vital that the Institute have a clear idea of what it hopes to do, and ensures that it has provided itself with the time and resources to effectuate those plans in a deliberate and sensitive manner.

O. ROBERT SIMHA

Housing and Food Services

During the year a facilities program for a new undergraduate residence was completed. The architectural firm of Sert, Jackson and Associates and Turner Construction Company are proceeding with a "design-build" concept. Construction was started early this spring and will be completed for occupancy in August 1981. The house will accommodate 352 students, eight graduate residents, and a faculty resident. It will include a central dining room and after-hours grill.

The report of the Committee on Campus Dining, chaired by Professor John Kassakian, was presented to the Chancellor in fall 1979. The announcement of the recommendations and programs, made in spring 1980, recognized that the Institute has a basic responsibility to provide food services on campus at a reasonable cost to students, that it must address health and safety concerns, and that dining must enhance and complement the quality of the campus residence program. This department, the Office of the Dean for Student Affairs, students, and members of the community have developed and are proceeding to implement a program to meet these goals. There will be a combined room and board plan required for those students living in houses with a central dining room and East Campus and Senior House. This will be phased in starting with the freshman class this fall. There will be a range of plans offered to all other students. With the use of a "transaction processor" (Vali-Dine Computer System), the flexibility of using plans for commons or a la carte purchases in any unit is permitted. Using these plans as a nucleus of operations, there will be variety of special menus, services, and programs offered to the student community. These offerings and operations will be reviewed continually throughout the next academic year, adjusting or changing as necessary.

The major maintenance program to maintain the integrity of the physical plant and upgrade the quality of the residential facilities has continued through the year. Major projects completed were renovations to the graduate resident facilities in Baker House; the conversion of Westgate's independent boiler unit to the central steam system; the installation of a new heating plant; and replacement of windows, lighting, and insulation of the roof at Random Hall. These projects at Random Hall were energy conservation related and funded by the Department of Housing and Urban Development. The sprinkler protection program, planned in conjunction with the Safety Office, is proceeding with the completion of Eastgate kitchens and partial installation in the Westgate low-rise buildings. Numerous smaller projects, including renovation or upgrading of student activity facilities were completed in several residences.

Many personnel changes have occurred over this past year. George E. Hartwell joined the department as Associate Director and John T. McNeill was promoted to Operations Manager of Food Services. Other supervisory and hourly positions which have been vacant for some time have been filled as a result of the implementation of the dining program. Ten persons retired with a total of 204 years of service at the Institute.

Campus Patrol

This year has been extremely busy with the new residence planning and the implementation of the new dining program. The department members have been very responsive to this added work load and deserve special acknowledgment.

HARMON E. BRAMMER

Campus Patrol

During 1979, the Campus Patrol provided 24-hour professional police and emergency medical services coverage to the MIT community, as well as other assistance services such as escorts and lockouts.

The number of complaints handled by the department for 1979 was down from the 1978 total. Of these complaints, 28 were in the crimes against persons category.

Although overall there was very little change in most of the serious crime categories, the incidence of armed robberies increased over last year's total.

Larceny is the largest category of crime that the Campus Patrol has to contend with. Institute property losses rose in 1979 and dormitory larceny totals crept upward as well. Extreme upswings in these figures continue to be curtailed by the department's yearly crime prevention programs. The Crime Prevention Unit's ongoing goal is to increase the awareness of the community to the risk of criminal victimization and to foster a belief in the responsibility of every individual to take reasonable steps to reduce that risk to an acceptable level.

There was a substantial decrease in the number of motor vehicle thefts reported to the Campus Patrol in 1979, but the greatly increased use of pedal power on the MIT campus during this year made bicycle theft a lucrative campus crime, and set a record high in this category for the past five years.

In the vital area of emergency medical service, the Campus Patrol ambulance and Emergency Medical Technician officers responded to over 1,700 requests for medical assistance, an increase over the 1978 total. This figure includes emergencies, patient transfers, and shuttles for members of the MIT community and the Charles Stark Draper Laboratory. Approximately 7 percent of these runs involved emergency treatment for non-affiliated people such as visitors.

A continuously growing statistic for the past five years has been the total number of requests for escort service to remote areas of the campus after normal working hours. During 1979, the Campus Patrol provided over 5,600 escorts to members of the community.

In an effort to maintain a high level of professional competence in the field of law enforcement and emergency medicine, the Campus Patrol department continued its vigorous yearly refresher training programs for all officers.

JAMES OLIVIERI

Safety Office

In general, Safety Office activities have been stimulated by the increasing efforts in safety being made by Institute departments and laboratories. The Safety Office has been active in training and advising on how more of such formal programs can be established and safety procedures implemented.

Laboratory Safety

A major area of concern has been the waste chemical disposal program. The Resource Recycling and Reclamation Act administered by the EPA has increased pressures for proper handling, tracking, and disposal of hazardous waste materials. Reviewing the provisions of this Act and how it will impact on MIT has taken considerable staff time. The volume of chemical waste has increased about 10 percent this year, but the new regulations and increase in laboratory facilities could cause another significant increase next year.

The Laser Facility Safety Guide has been distributed to all laser users and personnel involved with evaluating facilities. Inspections of laser laboratories based on the new guide are in progress.

Education and Training

Cardio-Pulmonary Resuscitation (CPR) courses continue to be quite popular at the Institute and at remote field stations.

Safety training of physical plant employees and seminars on safety from laboratories and departments have risen sharply in the past year due to the increased awareness of safety brought on by the activity of the Institute Committee on Environmental Health and Safety.

Seminars on laboratory safety topics such as compressed gas, flammable liquids, and electrical safety were given to staff, faculty, and students in chemical engineering, physics, Lincoln Laboratory, and the National Magnet Laboratory.

Fire Protection

Advancements in fire protection are occurring on many fronts. New automatic sprinklers were installed in several of our buildings. The fire response information for the Autocall fire alarm system has been revised and updated, and a new microprocessor for the Autocall system will shortly replace the existing printers in the Work Control Center. Fire insurance inspections of the entire campus are continuing under our new fire insurance carrier, Kemper Insurance.

Physical Facilities and Research Projects

The review of building construction plans, space changes, and renovations for code compliance continues to be a major activity of the Safety Office, as does the review of new research projects which present significant hazardous potential. The Safety Office itself is researching and reviewing documents in the following areas: protective barriers and hazard evaluations for high pressure experiments, safety documentation and design safety criteria for coal gasification plants, review of fire protection for chemical laboratories, and the development of new safety standards for solar photovoltaic energy sources.

Off-Campus Sites

Safety services continue to be provided to our remote sites. Lincoln Laboratory is receiving major attention and significant strides have been made to upgrade the program, particularly via training efforts. In addition, Haystack, Millstone, Firepond, Endicott House, and the LINAC continue to receive attention.

Industrial Accidents

For the past year the number of compensable injuries per 100 employees (frequency) and the dollar losses per 100 employees has increased by less than one-tenth of one percent.

Graphic Arts and Audio Visual Services

Personnel

A significant event of the year was the retirement of Catherine Coleman as Administrative Assistant of the Safety Office after 21 years of dedicated service.

JOHN M. FRESINA

Graphic Arts and Audio Visual Services

For the fourth consecutive year, there were substantial increases in work order volume and gross revenues over the previous period, with all departments sharing in this volume. Total revenue was up approximately 15 percent to \$3.5 million for the year.

The continual modernization and updating of equipment in this fast-moving field has contributed importantly to the success of the Graphic Arts Service. Equipment purchases during the year include a new 11" x 17" offset press and a new typesetting unit with the capability of receiving data, via telecommunications, from word processing units at the Institute.

The Purchasing and Printing area, which includes administering and supervising approximately 25 high-speed copy machines on campus, as well as the purchasing of most printing and printing-related supplies, is functioning smoothly and effectively. Comments from the users continue to be favorable.

The four Copy Centers continue to increase their work volume and gross revenue despite space limitations. Total dollar volume was up approximately 15 percent over 1978-79. New equipment included one more Xerox 9400 two-sided high speed copier and a two-sided A & M Offset Press.

The Audio Visual section has been involved in updating sound and audio equipment at various MIT locations, particularly in our larger lecture halls.

JAMES W. COLEMAN

Purchasing and Stores

General Purchasing Office

The Office staff was augmented by transfer of personnel from two separate laboratory purchasing agencies, which had been phased into the central purchasing office, and by the addition of an Assistant Director of Purchasing and an Administrator for Systems and Procedures. This growth was necessary to strengthen the operation of the Office, and to accommodate a planned increased work load generated by the assumption of purchasing work of the Office of Laboratory Supplies and of the two separate laboratory purchasing agencies.

The number of orders processed and issued by the Office increased 60 percent for the year. More complex and high-dollar procurements received greater attention of staff purchasing agents, while low-dollar purchases, which represented 80 percent of the work load, were almost entirely the responsibility of office support staff under the supervision of staff purchasing agents.

New systems and procedures which served to streamline processing and strengthen the overall operation of the Office were developed and implemented. Standard Institute purchasing procedures applicable to procurements processed by on-campus purchasing agencies were also developed.

Vice President, Operations

Office of Laboratory Supplies

The transfer of non-related purchasing work, which consumed an inordinate amount of the staff's time, from this Office to the General Purchasing Office, and the addition of an Assistant Director of Stores, allowed for concentrating on the procurement of items carried in our stock-rooms for resale. As a result, significant first-year accomplishments were realized by means of the competitive bid and annual purchase processes. Savings realized were passed on to the Institute community by means of price reductions on some items, by retaining early 1979 prices on many items, and by pricing remaining items at favorable prices. Numerous new, generally popular items, customarily purchased from outside sources, were added to inventory at favorable prices and resulted in healthy sales activity.

The automated sales reporting/billing system, which was designed for this Office, was utilized for a second year for automatic pricing and billing of requisitions and the reporting of monthly sales performance. This system functioned consistently and accurately, and conclusively demonstrated its value as a labor-saving system and a highly useful management tool.

Purchasing Field Office

This Office was established at mid-year, as an extension of the General Purchasing Office, to process and administer the substantial procurement requirements of the Francis Bitter National Magnet Laboratory and the Plasma Fusion Center. The staff of this Office was drawn primarily from existing Magnet Laboratory personnel who were assigned procurement responsibilities. The Magnet Laboratory subcontract administrator was transferred to the administrative staff of the General Purchasing Office and was assigned responsibility as Purchasing Field Office Manager.

Separate Purchasing Agencies

By year end, the number of separate purchasing agencies involved in procurement under Federal contracts and grants was reduced from six to three. Steps will be proposed during the coming year to consolidate the work of one of the remaining agencies into the General Purchasing Office and to combine the remaining two agencies into one additional Purchasing Field Office. At that point, we will have significantly streamlined and strengthened on-campus purchasing operations and satisfied all Federal audit agency recommendations.

Minority Business Purchasing Program Women-Owned Business Purchasing Program

During the year, orders worth approximately \$600,000 were placed with minority business concerns. The number of orders issued is almost double the number issued during either of the two previous years. It would appear that our program is firmly in place and growing. We are doing business with a small number of women-owned business concerns, and a report of this activity for the year will be compiled and published.

Our affirmative action program and procedures governing procurement from minority business concerns were revised and renamed to align more closely with recently enacted Public Law 95-507. This is in respect to procurement from minority business concerns, and will include the requirement of the MIT Affirmative Action Plan with regard to procurement from women-owned business concerns as well as minority businesses. An automated commitment recording and reporting system is necessary, and is being developed for the vendor listings and the recording and reporting requirements of the new law.

By January 1980, the requirements of the law were being applied to new contracts awarded the Institute and amended to our existing contracts which exceeded \$500,000. The efforts of the Assistant Director of Purchasing to coordinate and compile the required subcontracting plans in a timely and satisfactory manner contributed significantly to the avoidance of extended funding delays under our contracts.

BARRY M. ROWE

Office of Facilities Management Systems

Facilities Inventory

The Office of Facilities Management Systems is responsible for the collection, maintenance, and reporting of data for more than 22,000 individual spaces at MIT, comprising nearly seven million net usable square feet. Using the MIT-developed space accounting system, INSITE II, two major updates to the space inventory were completed. Each update was followed by the distribution of several reports to academic and administrative officers, as well as numerous special reports produced throughout the year. Also, historical facilities data continued to be maintained in graphic and statistical form.

Of significant accomplishment, the new INSITE 3 space and property management information system for MIT was completed, tested, and placed into operation this year. Replacing INSITE II, it provides a more efficient data management capability, an extremely flexible report generator, and an English-like language for the non-computer oriented user.

INSITE Consortium

Another major responsibility of OFMS is to provide support to the existing consortium of external users of the INSITE technology, as well as to foster the continued growth of the consortium in both its membership and the quality of its facilities management. This past year saw four new members of the consortium: Columbia University, Emory University, Tufts University, and Lifemark Hospital Corporation. Each organization employs the INSITE system and its associated methodology to both manage their inventories of building space as well as to share their knowledge and experience in this area with MIT.

Property Management

During the year, almost 8,000 items of newly acquired pieces of movable equipment were identified and tagged with new bar-coded labels. Also, an inventory and appraisal of existing items of movable equipment was begun. Information about these items was input into the new INSITE 3 system to satisfy MIT's property management requirements.

Our program to acquire government excess equipment has been broadened during the past year.

OFMS also has been given responsibility for acquiring equipment from the State Surplus Warehouse in Taunton, Massachusetts. In addition, hardware items were acquired for the Physical Plant Department from the National Association for the Exchange of Industrial Resources, in which OFMS maintains a membership.

Also during the year, equipment in a general state of disrepair and unneeded by the MIT community was sold, and items of usable equipment were transferred for reutilization within the MIT community. To assist with these processes, OFMS opened an MIT Equipment Exchange store at 224 Albany Street (NW 30). At the Exchange, equipment is displayed and made available to any MIT organizational unit through no-cost transfers.

Storage Facility

The operation of the MIT storage facility at 224 Albany Street continued, providing storage to 27 departments. A building users group was formed, resulting in tighter security control of the building, and implementation of a storage tag system to assist both the storing department and OFMS to better control the use of existing space and the future reuse or disposal of the stored items.

KREON L. CYROS

Endicott House

Although day use of Endicott House remained approximately the same as the prior year, resident use was increased -- from 22 groups to 32 groups. A number of the groups were small, however (averaging 15 guests per night), therefore our total number of overnights was not much higher than that of the prior year. Resident use of the house was extremely low during the months of August, December, May, and June. January was well booked, both for resident conferences and day use.

The house was used 278 days and 183 nights during the year. Of the 32 resident conferences held, 18 were MIT groups, whose guests accounted for 4,028 overnights; 14 were non-MIT groups, whose guests accounted for 525 overnights. The total overnights, 4,733, gave us an average of 25.8 guests per night of operation.

Non-resident use of the house decreased slightly. There were 117 non-resident groups, with a total of 7,793 guests, who used the house. Of these, 89 were MIT groups, whose guests totaled 6,217; 28 were non-MIT groups, whose guests totaled 1,576.

A total of 22,721 meals were served during the year, an average of 81.7 meals per day of operation.

We again closed the house for a two-week period in August 1979, to work on capital improvements. Several much-needed renovations were completed at that time and a security system was installed during the year.

AIMEE PIERSON

Vice President, Research

The 1979-80 year has been a good one. The Energy Laboratory grew faster than inflation (15 percent) but not as dramatically as the previous year (25 percent). The \$12 million research budget consisted of 65 percent government grants and contracts, and 35 percent from industry and foundations. The Energy Laboratory made significant contributions to the educational program through the involvement of 45 faculty and over 250 students (graduate and undergraduate) in research projects. Research material was used in 40 academic subjects. The number of associated organizations that support and relate to the research activities has increased by five percent to a total of 30. Anyone interested in the dynamics of this relatively new laboratory (founded in 1973) should read, as a minimum, the introductory summary of the Energy Laboratory report.

The Nuclear Reactor Laboratory (NRL) continued to build in-house research activities and attract new "customers" for services from the Institute-at-large. Plans are under way to expand life science-related research and neutron scattering research.

The Center for Materials Science and Engineering (CMSE) continues to be a major focus for interdisciplinary research in materials. Thirty-six faculty members are funded under the National Materials Grant Program of the National Science Foundation. Three newly appointed faculty members were provided seed funding from this source. The central facilities, available for use by the MIT community, were augmented by an additional scanning electron microscope and a computer image analyzer (the Quantimet). A major space problem was temporarily resolved by closing the Machine Shop (other Institute facilities are available). The space is being converted to office and laboratory facilities.

The Plasma Fusion Center (PFC) continues to make major contributions toward the achievement of controlled thermonuclear fusion. The Center is comprised of 25 faculty members from six departments, 80 staff researchers, 70 graduate students, and 50 support personnel. The NABISCO building was acquired as a gift this spring and presently houses 20 staff members. Plans are being developed to convert one wing of the building into a tandem mirror facility which will be a major addition to fusion research at MIT.

The Francis Bitter National Magnet Laboratory (FBNML), which has completed its 20th year, continues to expand its horizons. For example, the bacteria which, in this hemisphere, follow field lines to the north to find the ocean bottom have been found to have south-seeking counterparts in the southern hemisphere. The high-field nuclear magnetic resonance spectrometer, using a superconducting magnet which, after start-up, maintains its field for years without a power supply, has provided a new window for viewing the structure and behavior of biological materials for both MIT researchers and visitors. An MIT hybrid magnet is the world's only source of a continuous 30T (300,000 Gauss) magnetic field. The users organization, representing users of FBNML facilities from all over the world, has achieved a high level of maturity, and is represented by a committee which advises the laboratory on facility usage and facilities expansion. The magnet design group, which plays a key role worldwide in high field magnet design, is expanding into renovated facilities across Albany Street. These facilities will be joined to FBNML by an all-weather bridge at the second-floor level.

The Laboratory for Nuclear Science (LNS) has continued its outstanding research in heavy ion physics, intermediate energy physics, and high energy physics. The new facilities of the Bates Linear Accelerator at Middleton, including a new large experimental hall (80 x 120 x 50 feet high, underground except for 4 foot thick concrete roof), and support facilities, are nearing completion. Construction funds for a beam recirculation system, to increase the beam energy to 750 MeV, have been approved. Construction is to start in the fall with completion scheduled two years hence. Researchers abroad at DESY and CERN continue to develop insight into the basic structure of

matter -- gluon, leptons, and quarks. Techniques devised for research in basic physics continue to be adapted to needs of clinical medicine as well as researches in other disciplines. These spin-offs make clear that, in addition to the new knowledge of physics being generated, benefits are accruing that are immediately relevant to social needs.

The Research Laboratory of Electronics (RLE), MIT's oldest interdepartmental laboratory, now supports some 30 diverse research groups which incorporate approximately 75 faculty and 400 students (300 graduate plus 100 undergraduate). The research covers many topics, thus providing opportunities for a wide variety of student theses. During the past year, work done in the Laboratory served as the basis for 16 doctoral, 3 engineering, 15 masters, and 23 bachelors theses. The latest addition to the Laboratory is Professor Erich P. Ippen, formerly of Bell Laboratories. He and his students are involved in pico-second optical phenomena and devices. Experimental programs have been proposed to extend the current pico-second technology to infrared wavelengths and to study nonlinear dynamic processes in semiconductor materials and devices. The exciting researches of other groups are outlined in the RLE section of this report.

The Patent, Copyright, and Licensing Office received 142 invention disclosures, filed 8 patent applications, and filed 10 foreign applications corresponding to 14 US applications. Gross royalty income totaled \$1,441,331. National and international interest in medical/biological patents has increased considerably during the year.

The Patent Marketing Office works in close coordination with the Patent, Copyright, and Licensing Office. During the year a number of industries have been introduced to MIT's patent portfolio, resulting in \$340,000 of research support from patent marketing contacts.

These comments provide only a very partial insight into the remarkable spectrum of research activities of interdepartmental and special laboratories at MIT. The reports which follow give more complete and detailed coverage. In reading the reports, one should not lose sight of the ubiquitous and essential contributions of undergraduate and graduate students who work side by side with faculty and staff to generate the kinds of research results which characterize MIT.

THOMAS F. JONES

Francis Bitter National Magnet Laboratory

This past year, the twentieth in the life of the Laboratory, was again a year of accomplishment and change. The administrative transfer of the Alcator thermonuclear fusion program to the Plasma Fusion Center was completed during the year. However, the two organizations will continue to share certain personnel, laboratory, and office spaces and to work jointly on several projects.

The Laboratory continues to be the leading Laboratory in the world for high magnetic field science and technology. FBNML achieved the highest continuous field (30 T). It has the largest variety of high-field magnets and these are used by the largest and most diverse group of researchers in the world. The Laboratory's users' program has achieved a high level of maturity. The number of users and their geographical distribution has expanded significantly, giving the Laboratory a true national status; the strong interaction with the Users' Committee has been providing guidance for facility usage and improvements.

The Laboratory continued its educational activities. A summer session course on the engineering of superconducting magnets for magnetohydrodynamic generators was given once in the summer of 1979 and again in June 1980. Dr. Roshan Aggarwal and Dr. Donald Stevenson taught undergraduate physics subjects. Twelve MIT graduate students were directly associated with the Laboratory, 10 of whom were supported as research assistants. Other graduate students from MIT and many other institutions used the Laboratory's high-field facilities in their physics research.

The Laboratory's research programs are of an interdisciplinary nature in that they provide for the high-field needs of the faculty and research staff of a number of academic departments and other laboratories at the Institute. In particular, the Laboratory maintains a strong interaction with the Departments of Physics, Chemistry, Electrical Engineering and Computer Science, Materials Science and Engineering, Mechanical Engineering, and Nuclear Engineering. In addition to an extremely close collaboration with the Plasma Fusion Center, the Laboratory interacts with members of the Center for Materials Science and Engineering, Energy Laboratory, Lincoln Laboratory, Research Laboratory of Electronics, and Whitaker College of Health Sciences, Technology, and Management.

The Magnet Technology Division of the Laboratory is recognized as a national resource for magnet research and development. The ultrahigh homogeneity 12 T superconducting magnet for 500 MHz Nuclear Magnetic Resonance (NMR) is now operational. The NMR facility has been rated by the National Institutes of Health (NIH) Advisory Committee as "the leading Biotechnical High Resolution NMR Laboratory in the world." The 12 T magnet operates with a homogeneity of one part in 10^8 over a 5 mm sphere. It is wound with niobium-titanium composite wire and operates in a persistent mode with no observable drift. The Laboratory now has three 5.4 cm bore water-cooled magnets which generate at least 19 teslas, including one of improved homogeneity; 22 teslas is available in a bore of 3.3 cm. Approximately half of the Laboratory's magnets now employ the new cooling configuration, and consequently are significantly more efficient than before. Our hybrid magnet is being assembled and is scheduled for operation by fall. This magnet is expected to generate 25 teslas in a 5.4 cm bore or 30 teslas in a 3 cm bore. The superconducting part of this magnet will be integrated with the closed cycle liquid helium facilities which the Laboratory has built up over the past year. The first two of a set of three superconducting coils made of filamentary niobium-tin have been received from Airco. These coils, together with a third, will constitute a 15 tesla superconducting magnet. This is a cooperative program with Airco whose aim is to advance the technology of filamentary niobium-tin magnets. Quasistatic fields up to 35 teslas have been generated with a new coil structure and with a cooling cycle of about 20 minutes between pulses. Design continues on a liquid-nitrogen-precooled magnet to generate 50 teslas for one second. Recent calculations reveal that the goal is very ambitious, unless a conductor of exceptional strength and conductivity can be developed. We are studying a laminate of pure copper bonded to high-strength stainless steel.

The National Magnet Laboratory scientific staff provides for cross-fertilization between the high magnetic field needs of the research community and the Operations and Technology Divisions. A number of the research projects are beneficiaries of close scientific collaboration with the users' community. The National Science Foundation (NSF)-funded program supports research in the area of solid state physics, spectroscopy, and biophysics. Some highlights of a number of projects in this program are given below along with those of other projects:

The Lifshitz point, a new type of multicritical point which was predicted recently, was observed for the first time in the magnetic material MnP. Experiments with a series of fractional monolayer thicknesses of Pt on Al thin fibers have confirmed earlier results which indicated that for superconductors in high magnetic fields, the theory of the critical field is inconsistent with spin-polarized tunneling results, even when the largest plausible correction for electron-phonon renormalization is included. It has been shown by spin-polarized tunneling that the first two atomic layers of Ni on a normal metal substrate are not ferromagnetic. In contrast, Fe is ferromagnetic in layers whose average thickness is less than one monolayer. Studies of the effects of stoichiometry and atomic order on the upper critical field V_3Ga were completed. A powder metallurgy process has been demonstrated for fabrication of fine fiber multifilamentary NbAl, a high-field superconductor.

In the theoretical study of negatively charged donor (D^-) centers in solids, two new effects have been discovered for the ground state binding energy. First, there is a remarkably large ratio of D^- to donor binding energy in polar crystals in which the electron- L_0 phonon interaction is strong. Second, the first decreases with increasing applied stress until a minimum is reached; increasing the stress still further then results in an increase of binding energy of the center. High resolution spectroscopic measurements on helium atom Rydberg states using CO_2 and far-infrared lasers and anticrossing spectroscopy have been extended. A new program to study the laser-induced photoionization of helium Rydberg states has been initiated. Magnetic fields of up to 20 teslas are needed and are now being used to implement the far-infrared photoconductivity method of identifying and studying unintentional contaminants in ultrahigh purity epitaxial GaAs. The donors, such as Ge, Se, Si, and sulfur, have been identified in concentrations as low as

$10^{13}/\text{cm}^3$. An extremely high resolution Fourier transform spectrometric system has been developed for solid and gaseous state spectroscopy in the millimeter and submillimeter wave region. Resonant magneto-Raman scattering experiments from two-dimensional electron gases in GaAs-AlGaAs semiconductor superlattices have been initiated in collaboration with researchers from Northeastern University and Bell Labs. These experiments have been motivated by theoretical suggestions that strong magnetic fields promote the formation of a highly correlated ground state due to electron-electron interactions.

A pulsed nitrogen laser was developed and integrated into a Schlieren photography system to measure the blast-wave expansion of laser-produced plasmas from solid and gaseous targets. A theoretical study had indicated a number of advantages of four-wave scattering from plasmas over conventional Thomson scattering diagnostics. A study of the feasibility of using these techniques to measure embedded magnetic fields is under way. An investigation has been initiated on the free electron laser operation, including the effects of cyclotron resonance enhancement and nonlinear mixing of two wiggler fields.

Bacteria from marine and fresh water sediments in Australia and New Zealand have been found to orient themselves in the earth's magnetic field and swim along magnetic field lines to the south. Similar bacteria had previously been discovered in New England sediments that swim to the north. Because of the inclination of the earth's magnetic field, both northern and southern hemisphere bacteria migrate effectively downward toward the sediments by swimming in their respective directions.

A number of new results have been obtained by the NMR groups in addition to the successful operation of the 500 MHz spectrometer. Purple membranes from Halo bacteria were oriented in a high magnetic field. Magic angle spinning equipment was developed for resolving shifts and dipolar couplings in solids. Preferential gauche-trans isomerization was observed in polymethylene lipid chains. Novel heteronuclear 2-dimensional NMR spectroscopy techniques were used to detect ^{15}N with greatly enhanced sensitivity, to indirectly detect the broad resonances of ^{199}Hg , and to determine non-polar proton-proton couplings in nucleotide spectra where the conventional proton spectra are too crowded for analysis. ^2H NMR studies of biological membranes in Sinbis virus, myelin, and sciatic nerves were carried out. The interaction of a local anesthetic at physiological concentrations with rat sciatic nerve was observed by NMR for the first time.

The Low-Field Group has continued its research in several areas of biomagnetism. These include studies of the sources of magnetic fields in nerve and muscle cells, use of magnetic dust as a tool to evaluate the condition of the lung, use of magnetic field measurements to determine electrical sources in the heart and brain, and theoretical studies of the limits to the amount of information about such sources that can be provided by magnetic measurements.

A facility has been established for studying means by which vehicles can be launched to very high velocity by electromagnetic accelerators, using stored electrical energy. This technology is of interest for hypervelocity artillery, the launching of reconnaissance and cargo vehicles, and for possible use in space. The most exciting potential application is the launching of cargo into space by electromagnetic catapults which can operate at mass ratios approaching unity, and at extremely low costs.

The capture of micron-size diamagnetic mineral particles by high gradient magnetic separators has been demonstrated and is the subject of a continued study. Separation of magnetite from coal, a necessary step in coal cleaning, has been performed at very high process rates with little loss of coal. Plans have been made for a pilot-scale demonstration under Department of Energy sponsorship. A fundamental study of the magnetic particle capture mechanism showed that the magnetic dependence on particle size can be characterized by a single dimensionless ratio.

The Laboratory continues to serve as the Department of Energy, Magnetohydrodynamics Division Field Office, managing the national program for magnet technology development and magnet system procurement. In addition to continued achievement in broad-range superconducting magnet technology development program, two large conventional magnets have been delivered, one to the Montana Component Development and Integration Facility (CDIF) (built by the Magnetic Corporation of America) and the other to the AVCO Everett Research Laboratory (built by Everson Electric & Bethlehem Corp.). Three very large superconducting magnets are also under

construction, one for the Montana CDIF, one for the Coal-Fired-Flow Facility at the University of Tennessee Space Institute, and the third for the Stanford University High Temperature Gasdynamics Laboratory. These magnets are being built by General Electric (Schenectady) Argonne National Laboratory, and General Dynamics, Convair Division, respectively.

BENJAMIN LAX

Center for Materials Science and Engineering

The Center for Materials Science and Engineering (CMSE), formally located in the Vannevar Bush Building (Building 13), features an interdisciplinary materials research effort primarily through a core-funding program sponsored by the National Science Foundation. This major effort, which is part of the National Materials Research Laboratory Program of the National Science Foundation (NSF/MRL), provides a focus for materials research at MIT. In the past year, 36 faculty members were funded under the NSF/MRL program. In addition to the formal research effort, SEED funding of newly appointed faculty, and junior faculty members in the materials area is undertaken within budget constraints. During the past year, three such programs were initiated.

The NSF/MRL supports interdisciplinary research programs in the following areas of thrust: Predicting Flow and Fracture in High Temperature Alloys, Deformation and Fracture in Polymer Composites, Structure and Properties of Microcrystalline and Glassy Metals, Platinum Surfaces and Platinum Based Catalysts, Optical Materials and Devices, Amorphous Semiconductors, Microelectronic Materials and Device Structures, and Phase Transitions. This program represents an interdisciplinary research effort of faculty from the Departments of Chemistry, Chemical Engineering, Electrical Engineering and Computer Science, Materials Science and Engineering, Mechanical Engineering, and Physics.

In addition to the NSF/MRL funding, research support is provided by small block grants or individual research grants through the National Science Foundation, Department of Defense Agencies, Department of Energy, National Institutes of Health, and other government agencies; through industrial sponsorship; through Fellowship support by a variety of sponsors, and through critical SEED fund support by the Institute, itself. The excellent cooperation of the various research sponsors with CMSE has contributed to making the effectiveness of the total research program greater than the sum of its parts.

A second phase of CMSE operations is the service to the MIT materials community as a whole through the organization and operation of central facilities. In this connection, the Center provides and maintains state-of-the-art equipment and facilities for the overall materials programs at MIT through funds from the NSF/MRL program, augmented by the MIT administration through supplemental funds for the purchase of major items of equipment. We are deeply grateful to the MIT administration for this continuing support. In the past year, the capabilities of our materials research program have been significantly enhanced by the upgrading of several of our facilities. In particular, the Microelectronics Central Facility has been greatly expanded both in space and equipment. Most importantly, an ion implanter has been acquired with NSF/MRL and MIT funds, allowing controlled injection of dopants to be made in semiconductor and other specimens. A new scanning electron microscope (SEM) has provided both increased research capabilities and eased the long waiting times for access to SEM equipment. A new computer image analyzer (the Quantimet) has provided new capabilities for quantitative analysis of electron microscope micrographs. Every year, major new advances must be made in our research facilities to enable the MIT materials community to remain at the cutting edge of the rapidly developing materials research field.

In addition, for the benefit of the entire materials community, CMSE publishes a yearly compilation of materials research programs, and also a compilation of polymer research programs at MIT. Colloquia series in these two areas are also sponsored by CMSE, featuring speakers from other universities, government agencies, and industry, as well as MIT faculty. Through these activities, CMSE provides yet another focal point for materials research at MIT.

Listed below are brief highlights of a few of the research efforts currently under way under the core-fund. We have taken samplings from each area of thrust, as well as from the several departments who participate in this program.

RESEARCH

Fatigue Crack Initiation and the Growth of Short Cracks in Nickel-Based Superalloys (Professor R.O. Ritchie)

In this research effort, significant advances are being made in the study of microcrack formation and propagation. Using periodic surface replication of low cycle fatigue specimens, fatigue crack propagation measurements in René 95 have been obtained for extremely small 0.1 mm cracks, representing size-scales two orders of magnitude smaller than conventional measurements. Such data have been compared to fatigue crack propagation behavior of long cracks (20-30 mm) above 10^{-8} mm/cycle, determined by incremental-load shedding tests using standard compact specimens. Preliminary results indicate that long crack propagation rates exceed short crack rates by up to one-half an order of magnitude at growth rates above 10^{-6} mm/cycle. Associated scanning electron microscopy was performed using CMSE central facilities. In addition, all mechanical testing was performed on equipment partially funded by CMSE, including test facilities in the Materials Science Department.

Micromechanisms of Creep-Fatigue Interactions in Nickel-Based Superalloys (Professor J. B. Vander Sande)

This research program applies state-of-the-art electron microscopy techniques to study microstructure and micromechanisms of creep-fatigue interactions in nickel-based superalloys. The microstructure of two γ' strengthened nickel-based superalloys, Astroloy and René 95, has been characterized using bright-field, dark-field, and weak-beam TEM techniques in conjunction with high spatial resolution chemical analysis provided by the STEM while operating in the energy dispersive X-ray analysis mode. Conventionally processed Astroloy and both conventionally processed and hot-isostatically-pressed (HIP) René 95 have been examined to identify second phase size distribution, morphology, interfacial characteristics, and chemical composition.

The microstructure of as-received HIP René 95 samples basically composed of a tri-modal distribution of γ' particle sizes (1 to 2, 0.25 to 0.50, and 0.01 to 0.05 microns in diameter) embedded in a nickel rich matrix. The smaller γ' particles are coherent, while the interfaces of the larger particles contain dislocation structures. In addition to the γ' particles, carbides in the range of 0.1 to 0.5 microns in size are present. Similar information has been obtained from observations of the as-received microstructures of conventionally processed René 95 and Astroloy. From these microstructural observations, Professor McClintock has been able to obtain microstructural input necessary for modeling the mechanical behavior of these alloys.

Characterization of the microstructure of TEM foils produced from the region near the fracture surface of René 95 has been accomplished. While the microstructure has been found to consist of very complex structures, some insightful information has been obtained for Professor Pelloux for his mechanical testing work on these alloy systems.

Plastic Flow Relations for High Temperature Alloys (Professor F.A. McClintock)

From a physical point of view, the formation of a grid of crossed screw dislocations has been developed qualitatively, showing how a cell wall can develop from its edges and how its formation and unraveling can contribute to the Bauschinger effect or to primary creep. At the same time, the micrographs obtained in related work by Professor Vander Sande and Dr. Sherry, using the CMSE central facilities, show that in high strength nickel-based alloys the dislocation structure is highly homogenous, so a three-dimensional analogue of a developing cell-wall is required for those materials.

In studies of environmentally affected creep crack growth, two fracture criteria have been developed: a steady, atom-by-atom crack advance due to loss of cohesion at the tip, and an intermittent fracture process resulting from grain boundary cracking at a point one grain boundary ahead of the crack tip. Theoretical estimates from these criteria are consistent with data showing important environmental effects at the long times expected in service.

Mechanisms of Viscoelastic Deformation and Physical Aging in Filled Polymers
(Professor R.E. Cohen)

Two experimental findings and one computer modeling result highlight this program of Professor Cohen. In the area of the viscoelastic response of carbon-filled elastomers, an unequivocal assessment has been made of the role of carbon-carbon interactions in the early stages of deformation. This was accomplished using a novel combination of creep T-jump experiments and electrical conductivity-creep experiments. A second experimental highlight involved measurements of the time dependent response of a crosslinked polystyrene sample to sudden changes in temperature and pressure; the success of a home-built and designed experimental piece of equipment now provides the capability of examining important mechanisms of physical aging in homogeneous glassy polymers and in heterogeneous polymers in which the continuous phase is glassy. Finally in the area of computer modeling, an existing model for volume recovery of glassy polystyrene has been used to demonstrate the feasibility of a method for separating the temperature and free volume contributions of aging in glassy polymers.

Mechanical Properties of Polymers and Glasses
(Professor D.R. Uhlmann)

During the past year, the surface chemistries of high purity, analogue glasses were determined using ESCA analysis. The special glasses were prepared over a range of composition using the vapor phase transport techniques employed in the production of optical waveguides. The results indicated that it is possible to simulate the standard fiberglass compositions, with selected constituents either removed or added. Treatment of these compositions with organosilanes have indicated effective coupling of the silanes to silicon, aluminum, and boron moieties on the surface, and less effective coupling to the calcium moieties.

In other work carried out during the year, it has been possible to increase the strength and fracture toughness of anhydride cured epoxy resins reinforced with milled fiberglass by 50 percent or more. These dramatic improvements in mechanical properties have been achieved by control of the length-to-diameter ratios of the fibers, as well as by appropriate selection of the organosilane coupling agents. Dramatic effects of fiber length on melt viscosity were also observed, as was pronounced coupling of the effects of volume fraction and length-to-diameter ratio of the fibers. These results have important implications for the production of fiberglass reinforced composites made with discrete fibers. The work made extensive use of the transmission electron microscope, scanning electron microscope, Auger and ESCA central facilities, and would not have been possible without these facilities.

The Corrosion Behavior of Amorphous and Microcrystalline Alloys
(Professor R.M. Latanision)

Microcrystalline alloys produced by rapid quenching have been found in some cases to have superior corrosion resistance when compared to otherwise equivalent wrought alloys of the same composition. During the past year, the corrosion resistance of Li-modified 2024 aluminum alloys have been examined in conventional and microcrystalline form. With the aid of Professor N.J. Grant, microcrystalline specimens containing 1 and 3 weight percent (w/o) Li were produced and subsequently examined potentiostatically in aqueous chloride-free and chloride-containing sulfate solutions. In chloride-free solutions, the 1 w/o Li microcrystalline alloy is more resistant to uniform corrosion than the 3 w/o alloy. In the presence of chlorides, however, the reverse is true -- i.e., the 3 w/o alloy is more resistant to pitting or localized corrosion than is the 1 w/o alloy. The greater susceptibility of the partially segregated 3 w/o alloy to general corrosion suggests that the segregated phases are indeed sites of high chemical potential. On the other hand, it appears that these same sites are not effective in pit propagation, perhaps because their homogeneous distribution may stifle pit initiation.

During the past year a potentiostatic polarization comparison was also made on three stainless steels having grain diameters ranging from 2 (microcrystalline) to 100 microns (conventional wrought material). Alloys were either fully austenitic or of an austenitic/ferritic microstructure. The microcrystalline alloys are found to be consistently more corrosion-resistant in acid chloride environments than their wrought counterparts. Likewise, reverse scan polarization measurements indicate that the microcrystalline alloys are far more resistant to localized corrosion (pitting) even in the case of the multiphase alloys. These observations are clearly of commercial importance.

Mechanical Properties of Metallic Glasses and Microcrystalline Alloys
(Professor A.S. Argon)

During the past year, research on mechanical properties of metallic glasses has progressed on two fronts:

- 1) To test the correspondence between the free volume distribution of a simple glass and its distribution of free energies for shear relaxations, computer models were developed that utilize the well-established techniques of molecular dynamics. Such computer models using pseudo-potentials were found to be quite suitable to explore the stable portions of sheared cluster configurations. They were, however, unmanageable for the modeling of the unstable portions of potential activation configurations that are also necessary for obtaining the total activation free energy for the shear transformations. In view of this difficulty, the disordered bubble raft in which all transformations are critically damped was developed further as a quantitative analog by obtaining a generalized two-bubble potential. This potential is currently being used to determine the potential energies of transforming configurations filmed in sheared bubble rafts.
- 2) A simple experimental method has been developed to measure the embrittlement in a series of $\text{Cu}_x\text{Zr}_{1-x}$ glasses that have been aged for increasing lengths of time below T_g , with accompanying experiments of differential scanning calorimetry and scanning electron fractography. The source of this embrittlement which is likely to be a result of the changes in the low end of the free volume spectrum is not yet clearly established and will be explored by means of measuring the effects of aging on the relaxation spectrum probed by internal damping experiments.

Spectroscopic Investigations of the Relationship of Substrate Structure to Adsorbate Complex Formation
(Professor F.R. McFeely)

One of the most important goals of small-molecule surface spectroscopy is to determine the relationship between the geometry of the surface and the structure of the adsorbate complex. A system for which this problem has been widely addressed is adsorbed carbon monoxide, which is an important reactant for the practical catalytic synthesis of methane and higher hydrocarbons. By a combination of angle resolved UPS and electron energy loss experiments, a detailed picture of CO chemisorption on low-index single crystal planes of numerous metals has been synthesized in the last few years showing that the bonding is basically similar to that in gas-phase transition metal carbonyls.

During the past year, the study of the structural chemistry of carbon monoxide chemisorption from ideal low-index surfaces has been extended to study highly stepped surfaces. These stepped surfaces provide a more realistic model for the type of surface structures present on the small crystallites upon which practical catalysis occurs.

Experiments were carried out on the (311) surface of copper, which consists of 2 atom wide "terraces" of (111) and 2 atom high (100) "steps," and thus provides maximum step density. Angle resolved UPS experiments were performed on this system with the aid of a home built two dimensionally rotatable photoemission spectrometer. HeII photons, polarized to approximately 93 percent purity by multiple reflection were used as a photon source. This system is the first instrument with sufficient sensitivity to employ such a polarized source in a laboratory setting, and this polarization dependence of the photoemission spectra is a powerful tool for the elucidation of the molecular orientation.

The experiments revealed the existence of a fundamentally new and unexpected mode of adsorption, with the CO molecules lying flat in the surface in the troughs created by the steps. While this coordination is unknown in transition metal cluster compounds (the closest analog being the iron "butterfly" compounds), it may be extremely important in the mechanism of the Fischer-Tropsch methane synthesis on catalytically active metals. The first step of this reaction is thought to be carbon-oxygen bond scission, and this coordination can facilitate this step in two ways. First, the large interaction between the $2\pi^*$ molecular orbitals and the surface afforded by this configuration will be much more efficient in weakening the CO bond than conventional backbonding. Secondly, the molecule is oriented such that both atoms may be highly coordinated to the surface as the bond is broken. For conventionally bound molecules, this may be achieved only by a presumably activated reorientation step.

Environmental Effects on Adsorbate Structure and Vibrations (Professor R. Silbey)

The effect of environment at a surface on adsorbate binding and dynamics has been of interest for the last few years. Recently, Professor Silbey and his group discussed an unusual effect which can occur when the environment of an adsorbed species varies in a statistical manner. The motion of an adsorbed atom along a surface is an important step in many surface chemical reactions. In most cases, the jumping from one site to another is activated, and if the activation energy Δ does not vary from site to site, then the motion of the adsorbed atom is diffusive. However, if the activation energy varies from site to site randomly, then there will be a distribution of jump rates. During the last year, the conditions on the distribution of Δ necessary to make the motion of the atom diffusive and the conditions which make the motion nonclassically diffusive have been developed. It is concluded that this effect must be taken into account in the usual theories of migration on solid surfaces.

Charge-Flow Studies of Amorphous Semiconductor Films (Professor S. Senturia)

An experimental technique for determining the intrinsic defect density in undoped semiconductor films has been developed and successfully demonstrated in an amorphous chalcogenide film. A charge-flow transistor (CFT) is fabricated using the deposited semiconductor film as the gate material. One measures the variation of the CFT static transconductance with gate oxide thickness, from which the screening length of the semiconductor gate material can be inferred. The screening length is, in turn, a direct measure of the intrinsic defect density. This research program has drawn heavily on the capabilities of the CMSE Microelectronics Central Facility, in which all of the charge-flow transistors and related MOS structures have been fabricated. The amorphous semiconductor films used in this study were deposited in collaboration with Professor D. Adler, who also participated in the evaluation of experimental results.

Time-Dependent Spectroscopy of Photoluminescence in Chalcogenide Glasses (Professor M. Kastner)

The model of Kastner, Adler, and Fritzsche (KAF) explains the high density of defects found in chalcogenide glasses. These defects are the origin of a wide variety of peculiar electronic properties of the glasses including the negative-effective energy. The high density results from the creation of defects in pairs which conserve the number of covalent bonds, thus keeping the creation energy small. These pairs of defects must be oppositely charged in order to account for the observed pinned Fermi level. KAF pointed out that the long range coulomb interaction between charged defects must result in correlations in their positions just as for ions in solution. Kastner and Hudgens suggested that charge-transfer de-excitation of oppositely charged defect pairs might be the origin of the observed photoluminescence (PL). Higashi and Kastner reported the first measurement of the time dependence of the total light decay of the PL in $a\text{-As}_2\text{S}_3$. The observed t^{-1} decay is the hallmark of a PL process which involves recombination of spatially separated electrons and holes and is consistent with the charged-defect-pair (CDP) model but does not exclude other models. Two experiments completed this year provide convincing evidence that the CDP model is correct. First, Higashi and Kastner measured the time evolution of the PL spectrum and showed that the narrowing of the spectrum with time (in the time range 10^{-8} to 10^{-6}

sec) is consistent with the CDP model. Second, an experiment has just been completed which appears to exclude all competing models. PL excited with polarized light was found to be polarized. This requires that the excitation process involves charge-transfer between spatially separated localized states. Most important, the PL remained fully polarized over the time range ($<10^{-6}$ sec) during which the spectral evolution takes place. This means that the spectral evolution does not involve motion of the electrons or holes for such motion would depolarize the PL. This result provides strong support for the CDP model.

Electronic and Vibrational Structure of Defects in Amorphous Semiconductors
(Professor J. D. Joannopoulos)

A realistic theoretical approach has recently been developed for the study of the electronic structure of defect states in amorphous semiconductors. This approach delivers new information about the total energy of defects and about the origin, character, energy location, and localization of defect states. This is made possible by using realistic self-consistent pseudopotential calculations on periodic structures with large super cells containing defects. The total energy calculations involve summing over all occupied one-electron states and including the difficult repulsive terms involving ion-ion interactions and corrections to overcounting electron-electron interactions. Using trigonal Se as a test case the results have been very favorable with predictions of bond lengths and angles to within 2 percent and an absolute binding energy of an atom in the solid to within 10 percent of experiment. Moreover, preliminary results on neutral defects in glassy Se have indicated the following very important results. The controversy regarding the lowest energy neutral defect is resolved with the one-fold defect existing with a remarkably low formation energy of 0.5eV. The three-fold defect is found not to be even metastable. The very low formation energy of the one-fold defect is obtained because of a new bonding that occurs between the defect and its nearest neighbor. We have found that this bonding is unique among the chalcogenides and cannot exist in other semiconductors. Finally, this low formation energy is very important for it explains how it is possible to have many structural defects in these glasses.

Study of Process-Induced Defects in Semiconductors
(Professor D. Antoniadis)

Two effects of potentially great importance in understanding the fundamentals of point defect processes affecting impurity diffusion and oxidation of silicon have been discovered. The first is a very large enhancement of impurity diffusivity during the early phase (<15 min) of silicon oxidation at 1000° C. This enhancement appears to be related to the as yet unexplained very rapid initial oxidation of Si. In addition the diffusivity of the tracer impurity has been found to be non-isotopic during this early period. These observations were made possible by a new computer controlled capacitance-voltage apparatus recently developed in the CMSE Microelectronics Laboratory. This development continues by incorporating a novel data reduction technique that should allow the observation of impurity profiles very close to the Si/SiO₂ interface.

The second effect is the anomalous diffusion of arsenic in thermally grown SiO₂. It has been observed that in inert ambients, arsenic diffuses normally at concentrations below about 10^{20} cm⁻³ while it appears to become immobile when it exceeds this level. A similar effect is well known for As in Si and is attributed to clustering but has never been reported for As in SiO₂. Furthermore these experiments have indicated that the diffusivity becomes normal when the diffusion is carried out in the presence of oxygen. In addition to their obvious technological implications, these observations may lead to techniques for observing point defect processes associated with oxygen diffusion in the SiO₂ network, an area where very little understanding exists at present. This research uses the CMSE Microelectronics Laboratory for sample preparation, and the SIMS apparatus at the Earth and Planetary Science Department for the analysis.

Order-Disorder Phenomena in Micellar Systems, Concentrated Protein Solutions
(Professor G.B. Benedek)

Professor Benedek and his coworkers have demonstrated that it is possible to detect extremely low levels of antigens by detecting the inhibition of agglutination reactions at its earliest stages

using the angular anisotropy of the intensity of light scattered by the aggregating particles. The particles used are antigen coated polystyrene latex spheres cross-linked by antibody. The sensitivity of this assay is comparable to that of radioimmunoassay. This method, however, obviates the need for radioactive agents. A patent has been granted to MIT for this invention.

In another project, these workers have made the first determination of the critical exponents which characterize the divergence of the moments of the cluster size distribution for a condensing system of polyfunctional monomers as the sol-gel transition is approached. The critical exponents that have been measured differ very significantly from those predicted in the Flory-Stockmayer theory. These findings are important in testing the fundamental assumptions involved in the theory of the polymerization of organic molecules, three-dimensional percolation theory, aerosol physics, and in immunology. This work was conducted in collaboration with R. DeBlois of the General Electric Research Laboratory in Schenectady.

During the past year Professor Benedek and coworkers published a fundamental paper which relates experimental data on the growth of micells (of sodium dodecyl sulfate) to the magnitude and temperature dependence of two chemical potential differences which describe micellar self assembly. The success of the theory in fitting a wide variety of features of the data represents a major advance in the literature on micelles and should serve as a basis for future work analyzing micellar structures far from the critical micellar concentration.

Phase Transitions in Multicomponent Systems (Professor R.J. Birgeneau)

The two dimensional (2D) Ising model is among the simplest of all magnetic model Hamiltonians; historically in the field of phase transitions it has also proved to be the most important since it represents one of the few systems exhibiting a non-trivial phase transition for which exact theoretical results may be obtained. Similarly, the problem of percolation in a 2D Ising system has several very attractive features including a) an exact result for the phase boundary, b) an exact result for the temperature scaling function $-e^{-2J/kT}$ rather than temperature T itself, c) an exact result for the crossover exponent ϕ connecting the geometrical and thermal critical behavior.

A series of quasielastic and inelastic neutron scattering experiments on the system $\text{Rb}_2\text{Co}_c\text{Mg}_{1-c}\text{F}_4$ have been carried out. The experiments demonstrate that this system is an ideal representation of the 2D Ising model near percolation. These experiments demonstrate that a) there is a well-defined percolation threshold at concentration $c = 0.593$ as predicted for the nearest neighbor square lattice site percolation problem, b) the geometrical and thermal inverse correlation lengths are simply additive, that is, $\kappa(c,T) = \kappa(c,0) + \kappa(c_D,T)$, c) the temperature scaling field is indeed $e^{-2J/kt}$ rather than T itself, d) the thermal correlation length exponent $\nu_T = 1.32 \pm 0.04$ equals the current theoretical estimate for the geometrical correlation length exponent $\nu_p = 1.35$ to within the errors, thus demonstrating that the crossover exponent ϕ is unity -- in agreement with theory, and e) the multicritical scaling function does not have a simple analytic form. Results b) and e) are not yet predicted by theory.

MILDRED S. DRESSELHAUS

Center for Space Research

Introduction

During the past year research in space science and technology at the MIT Center for Space Research (CSR) has been concentrated in the areas of X-ray astronomy, interplanetary plasma physics, and the life sciences. Investigations have been carried out using high altitude balloons, sounding rockets, earth orbiting satellites and interplanetary space vehicles. A specific objective during this period has been to broaden the present base of space experimentation in the life

sciences and studies of the surface properties of celestial bodies, but also to include studies of the upper atmosphere, gamma-ray, radio, optical, infrared and ultraviolet astronomy, solar physics, and earth and planetary spectroscopy. To further these objectives the staff of the Center for Space Research has been working with other members of the MIT faculty and research staff to develop topics in relevant disciplines that match the mutual interest of NASA and MIT. To this end the Center has provided the special capabilities and resources required for the initiation and development of several new programs. In special cases the Center has made special services available to research staff from other institutions.

In this report we give an overview of current programs being conducted within the Center for Space Research with special emphasis on topics which show promise as new areas of research compatible with NASA's planning for the 1980s.

ACTIVE PROGRAMS

Small Astronomy Satellite (SAS-3)

The SAS-3 flight program, under the direction of Professor George W. Clark, Department of Physics, completed almost four years of successful flight operations when it re-entered in April 1979. Professor Clark is assisted in this research by Professors Hale V. Bradt, Walter H.G. Lewin and Saul A. Rappaport, all of the Department of Physics. The satellite was under nearly constant direction from a control center at CSR during its active life. Some of the more interesting results obtained from SAS-3 during the past year pertain to X-ray bursters, binary X-ray sources, extragalactic X-ray sources, and soft X-ray emitters. The scientific results are discussed more fully in the report of the Department of Physics. With the re-entry of the SAS-3 satellite, attention has now been turned to in-depth analyses of all the data and continued publication of the results.

Scanning Modulation Collimator Experiment (HEAO-A-3)

The A-3 experiment on HEAO-1 is a joint MIT and Smithsonian Astrophysical Observatory (SAO) effort. Professor Bradt, Department of Physics (MIT) and Dr. Daniel Schwartz (SAO) are the principal investigators for this experiment. At MIT, Professor Bradt is assisted by Drs. Rodger Doxsey, and Mark Johnston. The A-3 experiment was activated two days after launch and performed as expected until the re-entry of the HEAO-1 spacecraft in March 1979. One of eight X-ray counters failed shortly after launch, but this loss reduced the experiment sensitivity only slightly.

The production data processing system was put together as a joint MIT/SAO effort. The bulk of the processing is accomplished at a dedicated mini-computer facility located at SAO. The production processing began shortly after the arrival of the first production data and has continued on a timely basis. At this time, the data from most of orbital operations have been processed and the analysis and interpretation of these data continues.

Scientific analyses of the processed data are carried out at both MIT and SAO. The primary goals of these analyses are: 1) locate accurately the positions of unidentified X-ray sources and make optical or radio identifications of the sources; 2) verify or refute suggested source identifications which have been proposed; 3) study the spatial structure of extended X-ray sources.

Hard X-Ray and Low Energy Gamma Ray Experiment (HEAO-A-4)

The A-4 experiment on HEAO-1 is a joint MIT and University of California at San Diego (UCSD) effort. Professor Lewin of MIT is the co-principal investigator; Professor L.E. Peterson of UCSD is principal investigator. Professor Lewin has been assisted by Drs. John Doty, Alan Levine, and Francis Primini, all research staff members of the MIT Center for Space Research.

The A-4 experiment was activated soon after launch in August 1977 and performed well until the re-entry of HEAO-1 in March 1979. Analysis of the A-4 data has primarily concentrated on three topics: the study of the high energy X-ray spectra of extragalactic objects; the study of the high energy X-ray properties of X-ray pulsars; and the construction of an all-sky catalogue of celestial high energy X-ray sources.

The results of studies of the observations of extragalactic objects include the first detection of a quasar, 3C273, at X-ray energies above 15 keV; in fact the measured spectrum extended to 100 keV.

Progress also has been made in the production of an all-sky high energy X-ray catalogue. "Skymaps," visual displays of large quantities of sky survey data, have been made for data from the first year of the mission. Preliminary inspection of these skymaps revealed that ~40 sources were detected at energies $E > 13$ keV, ~30 sources at $E > 25$ keV, ~15 sources at $E > 40$ keV, and ~5 sources at $E > 80$ keV. Systematic searches of this data base plus additional analyses are expected to significantly increase these numbers. We have recently performed minimum χ^2 fits of the intensities of 40 preselected celestial objects to the skymap data in the galactic center region. The results have greatly reduced the problem of source confusion.

Einstein Observatory (HEAO-B-3)

The Focal Plane Crystal Spectrometer (FPCS) experiment under the direction of Professors Clark (principal scientist) and Claude R. Canizares (senior project scientist) has operated flawlessly since activation in late 1978. The instrument has been used to make high resolution studies of X-ray emission lines from several dozen galactic and extragalactic objects. Long exposures have led to the discovery of more than a dozen emission lines in the spectra of supernova remnants (e.g., O VIII, O VII, Ne IX, Fe XVII, Si XIII, Si XIV, S XV, S XVI from Puppis A), clusters of galaxies (e.g., O VIII and Fe XXIV from the accretion halo of M 87 and Fe XVII from the Perseus cluster), and possibly the compact source Sco X-1. The rich yield of results has demonstrated the power of the FPCS to probe new aspects of the plasma processes responsible for X-ray generation in the brighter sources. For example, the intensities of lines observed from the supernova remnants are being used to derive accurate plasma temperatures, to establish the degree of ionization equilibrium in the plasma and to derive relative abundance ratios for selected elements. The M 87 and Perseus data give strong support to models which predict radiatively regulated accretion of intracluster material onto the dominant central galaxies.

High Altitude Balloon X-Ray Observations

High altitude balloon X-ray observations have been carried out by the Center through a long series of flights both in the Northern and Southern hemispheres since the late 1960s. This research has been under the supervision of Professor Lewin, assisted by Dr. George Ricker, Principal Research Scientist in the Department of Physics. For several years, the Cosmic Ray Working Group of Leiden University, The Netherlands, has participated in this research as a collaborator with MIT. The research uses very sensitive X-ray detectors to study galactic and extragalactic objects which radiate in the 18 to 150 keV range. These objects show burst and/or flare-like changes in source intensities having characteristic time scales 4 to 5 times shorter than can be observed by other X-ray observing techniques.

In May of 1979, a new X-ray detector with 1500 cm² area (energy range 20-200 keV) was successfully flown from the National Scientific Balloon Facility in Texas. This hard X-ray detector is the largest and most sensitive ever flown. During 10 hours of observing, three extragalactic and two galactic sources were studied. The extragalactic objects included a quasar, an N galaxy and a Seyfert galaxy. Observations of the N galaxy, 3C382, mark the first successful detection of hard X-rays (>50 keV) from this class of objects. Cygnus X-1, one of the two galactic objects studied, is widely regarded as a good candidate for a black hole. These observations of Cyg X-1 should permit more definitive tests of several predictions of black hole models for the source.

Sounding Rocket X-Ray Observations

Over the past several years, the MIT X-ray astronomy sounding rocket group, under the direction of Professor Saul A. Rappaport, has designed, constructed, and flown an imaging X-ray experiment. The system utilizes a low-cost X-ray telescope of the Wolter I type, with moderate angular resolution ($3'$) and a position sensitive proportional counter to record the X-ray image. The detector was built in collaboration with the X-ray group at the University of Leicester, England. The imaging payload was flown successfully on two Astrobee-F sounding rockets in July 1977 and in March 1978. During these two experiments, three old supernova remnants were imaged in soft X-rays ($E \sim 1$ keV): Cygnus Loop, Puppis A and IC 443. These represent the first true X-ray images of supernova remnants (i.e., recorded with imaging X-ray optics). These experiments also marked the first use of the Wolter I type telescope for imaging extra-solar system objects.

At present the sounding rocket group is designing a wide-field (8°) soft X-Ray ($50\text{-}250\text{\AA}$) camera for use on rocket-borne experiments and potentially on the Space Shuttle. The telescope objective will comprise three nested mirrors that are basically of the Wolter I type, but with surfaces slightly modified to minimize off-axis aberrations. The imaging detector will be a micro-channel plate (~ 50 mm diameter) to be provided by our collaborators at the University of Leicester. It is estimated that the first flight with the new wide-field camera could take place as early as spring 1981. This type of instrument is expected to yield important astrophysical results in five areas: 1) a study of stellar sources with characteristic temperatures in the range of $\sim 10^5\text{-}10^6$ °K; 2) a map of the ultrasoft diffuse X-ray background; 3) images of extended extragalactic sources; 4) images of nearby supernova remnants; and 5) discovery of new astrophysical classes of soft X-ray emitters.

Interplanetary Monitoring Platform (IMP-8)

The IMP 8 spacecraft continues to be an extremely important source for solar wind data at 1AU. We have used these data to compare with solar wind observations from the Voyager spacecraft out to a radial distance of 6AU in a study of the evolution of the solar wind with radial distance.

Voyager (Plasma Science Experiment)

The Voyager 1 and 2 spacecraft were launched in late August and early September 1977. Each spacecraft carries 11 separate science investigations, including a plasma experiment which is under the direction of Professor Herbert S. Bridge, Department of Physics. The Voyager Plasma Science Experiments are designed to investigate the properties of the distant solar wind and to study the magnetospheres of Jupiter and Saturn.

The recent Voyager 1 and Voyager 2 fly-bys of Jupiter, with closest approach on March 5 and July 9, 1979, respectively, were extremely successful in terms of the plasma science measurements. Before the Voyager encounters, it was known from ground-based observations that neutral sodium and singly ionized sulfur existed in the vicinity of the Galilean satellite Io. The *in situ* positive ion observations of the plasma science experiment confirmed the existence of S^+ , and in addition identified H^+ , O^+ , O^{2+} , S^{2+} , S^{3+} , SO_2^+ and Na^+ . Quantitative determinations of the densities and temperatures of these ions in the Io plasma torus are possible, and such information has been used to construct models of the spatial distribution of plasma in the torus. In addition to the positive ion measurements, the plasma science measurements of electrons in the Io torus have demonstrated the existence of both a cold and a hot electron population, with temperatures of ~ 10 eV and several hundred eV, respectively. A comparison of the *in situ* data on positive ions and electrons with that from other Voyager experiments, especially the ultra-violet spectrometer, should provide an explanation for the origin and excitation of the observed ionic species.

In addition to measurements near the Io plasma torus at $\sim 6 R_J$, the Voyager experiment obtained a wealth of information about plasma properties at greater distances. One of the most surprising results was that the Jovian plasma, which was theoretically expected to rotate with the planet out to great distances ($\sim 80 R_J$), actually begins to deviate from strict corotation as close in as $12 R_J$, and at $40 R_J$ is moving at less than 50 percent of the expected corotation velocity. It has

been suggested that this effect is a consequence of rapid plasma production by Io and weak atmosphere-magnetosphere coupling. Such measurements in the middle and outer magnetosphere are fundamental to the understanding of the overall plasma dynamics of the Jovian system.

The Voyager spacecraft are continuing on their way to Saturn, with the Voyager 1 Saturn encounter in November of 1980. Voyager 2 will encounter Saturn in August of 1981 and may be redirected toward a Uranus encounter in 1986.

Optical Studies of X-Ray Sources

A program to study the optical properties of X-ray sources has been carried out by Dr. Jeffrey McClintock and Professor Canizares. Most of the observations have been made at the McGraw-Hill Observatory in Arizona (operated jointly by Dartmouth, Michigan, and MIT) or the Cerro Tololo Interamerican Observatory in Chile. Highlights of the year's activities include: 1) the discovery of the optical counterpart of the X-ray nova Cen X-4; 2) simultaneous optical and X-ray observations of the X-ray pulsar 4U1626-67 show that much of the optical light originates within 1/2 light-sec of the neutron star; 3) the discovery of a remarkable O-subdwarf star in the globular cluster NGC6712; and 4) the discovery of six quasars at Einstein (IPC) X-ray positions. (Much of the work mentioned above was done in collaboration with Jonathan Grindlay of Harvard University.) In addition, four long-term projects have been started in the past year which will require substantial new observational data: studies of cD galaxies in poor clusters; a determination of the Roche geometry of the Hercules X-1 system (being done by Dr. Larry Petro); a monitoring program for detecting spectral variability in Sy 1 galaxies and QSO's; and the determination of distances to Sco X-1-like X-ray sources. Most of the work is currently tied to observations and discoveries made by the Einstein Observatory.

Mission Definition Study of a VLBI Network Utilizing the Space Shuttle

This research program under the direction of Professor Bernard F. Burke of the Department of Physics was initiated in April 1979. Its purpose is to investigate the concepts and methods of implementation of an orbiting Very Long Baseline Interferometer (VLBI) terminal in the space shuttle. Specifically, the effects of orbital perturbations will be examined and mission models will be constructed to identify an optimal strategy for the flight program. In addition, modifications to the existing VLBI software analysis routines which will enable these routines to accommodate an orbiting terminal will be identified and studied.

Reflectance Spectrometer Research for Possible Mars Orbiter and Comet Missions

The Center for Space Research is conducting preliminary design and breadboard development of a reflectance spectrometer instrument (RSI) to demonstrate the capability of an optical/IR spectrometer of moderate resolution to determine the composition of material of inner solar system bodies by studying their reflectance spectra. The instrument is able to resolve the spectrum to within 1 percent at a precision of 0.1 percent. In addition, by incorporating detectors in the direction perpendicular to the spectral dimension at the focal plane, spatial information is simultaneously obtained for several selected wavelengths. Other possibilities for achieving this spatial coverage are being investigated including a nodding secondary optical device which offsets the optical train from boresight. Detector evaluation is continuing as well as optical and electronic design so that a specific instrument can be designed readily for a potential Comet mission.

The research program is under the scientific direction of Dr. Thomas B. McCord of the University of Hawaii. Local supervision of the technical aspects is provided by Dr. Joseph H. Binsack of the Center for Space Research.

Spacelab 1 (Vestibular Experiments)

The program, being carried out under the direction of Professor Laurence R. Young, Department of Aeronautics and Astronautics, will provide a series of vestibular experiments on Spacelab 1 in the 1983 timeframe. The Center furnishes management and engineering support for the program.

Several Canadian co-investigators from the Defense and Civil Institute for Environmental Medicine are involved in this program to test theories of human reactions in the gravity-free environment of Spacelab. Seven separate experiments are planned, some in collaboration with European Space Agency investigators. The experiments 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 is assisted in the Spacelab experiments by Dr. Charles M. Oman of the Department of Aeronautics and Astronautics.

Other Research

Research by the staff of the Man-Vehicle Laboratory under the direction of Professor Young continued in the areas of: habituation to novel visual vestibular environments with particular reference to space flight; compensatory visual neural changes with eye movements; visual vestibular interaction and its application to flight simulation; special pedagogic strategies in arithmetic; and ski accident research. Professor Young is assisted in this research by Dr. Oman, Dr. Alfred Weiss, and Dr. Alan Natapoff, all of the Department of Aeronautics and Astronautics.

RESEARCH PROGRAMS FOR FUTURE NASA OPPORTUNITIES

Detector Technology

We have been pursuing the laboratory investigation of a new type of solid state detector made from mercuric iodide (HgI_2) currently manufactured by EG&G of Santa Barbara. The outstanding advantage of this detector is its ability to operate satisfactorily near room temperature as a non-dispersive spectrometer. All other semiconducting X-ray detectors previously used in X-ray astronomy have required cryogenic cooling ($T \lesssim -175^\circ\text{C}$). Other uses of HgI_2 as a photon limited detector (in contrast to a background limited detector) are also being investigated. New crystal growing techniques are becoming available which show promise of improving the inherent detector resolution to a value even lower than the currently achievable value of 300 eV at 6 keV. We are currently evaluating these new growth techniques in experiments we are conducting in vapor growth furnaces here at MIT. We are also collaborating with the University of Southern California Medical Imaging Science Group in further improving the detector manufacturing and signal processing techniques.

Two configurations for this instrument are being considered by Dr. Ricker and his colleagues. The first will be optimized for the energy range where reflecting X-ray optics are effective (.5 - 5 keV), and should be ideally suited for use as a focal plane instrument on the Advanced X-ray Astrophysics Facility since the detector should operate more than 5-10 years without degradation or the need for refurbishment. A second configuration will be optimized for high energies (>20 keV), and should be capable of detecting cyclotron and nuclear lines in cosmic sources at unprecedented levels of sensitivity.

A project on the exploratory development of a CCD camera was established to assist in the demonstration and proof-of-concept of the use of a Charged Coupled Device (CCD) sensor as an imaging X-ray and optical detector.

CCDs have developed very rapidly in the photosensor field and show great promise for future optical, infrared, and X-ray astronomy applications. They combine high quantum efficiency, wide dynamic and spectral ranges, and unusual geometric and photometric stability.

During the past year, Dr. Ricker and his colleagues have completed the initial phase of a CCD X-ray detector program. The principal goal of this phase was to demonstrate the detection of single photons, and was successfully achieved. The ultimate objective is to develop a detector for use as a focal plane instrument on a large, reflecting X-ray telescope (such as the Advanced X-ray Astrophysics Facility scheduled for launch in the mid-1980s). Such an instrument would offer uniquely high spatial and spectral resolution, good quantum efficiency, and long-term stability in a space environment.

New Concepts for Space Experiments

This project to support the development of new space experiments for which the Center for Space Research might have an active part in the conceptual design and engineering is intended to support promising ideas through the proposal phase, and during the past year several experiments have been developed to this point. These new experiments cover a wide range of space disciplines and applications and include the projects noted here.

In response to the announcement of opportunity for scientific flight investigations of Venus, MIT organized an investigation group under the leadership of Dr. Gordon Pettengill, principal investigator, to utilize the Synthetic Aperture Radar (SAR) on the Venus Orbiting Imaging Radar (VOIR) Mission. The major scientific objective of this proposal is to reveal those processes that have shaped the surface of Venus and led to the evolution of its distinctive atmosphere. A major intermediary in achieving this goal is the preparation of a global map of the surface morphology in sufficient detail to describe and locate the major geological types and processes exhibited by Venus.

In order to generate and interpret such a map, the proposal sets forth a plan involving a principal investigator and 10 co-investigators drawn from leading universities and research organizations. These investigators have been formed into task groups which will participate in and monitor the design and implementation of all aspects of the SAR Instrument, its operation during the flight phase of the VOIR Mission, the reduction of imaging and ancillary data, and the subsequent geological and geophysical interpretation of these data.

The proposal was selected in summer 1979 and the investigation group was augmented by nine additional co-investigators selected by NASA. Efforts are currently under way in support of the group's participation with the Jet Propulsion Laboratory (JPL) in defining the Mission and the SAR requirements and implementation.

An Interplanetary Baseline Interferometer (IBI) experiment has been proposed using the VOIR Spacecraft System as one element of the interferometer, together with radio telescopes on earth to study radio emission from pulsars. The major objective of the experiment is to see whether it is generally possible to operate a radio interferometer with an interplanetary baseline. The anticipated results bear directly on major problems of astrophysics associated with high resolution radio images of distant sources; they will to a great extent determine the future use and development of this technique.

The immediate purpose of the experiment is to use a pulsar as a transmitter of small angular size, and by analysis of the cross-correlation of the signals received on the spacecraft and on the earth, to derive the effect of the interstellar medium on the propagation of radio waves from distant radio sources. It also may be possible to measure the apparent angular sizes of the closest pulsars.

The longer-range purpose of the experiment is to determine the ultimate limits of the Very Long Baseline Interferometer (VLBI) technique. There are no limits, from the technological point of view, to the use of interferometer systems having a baseline of several astronomical units. A VLBI system of such size, if it could be realized, would have the capability of measuring parallaxes of very distant extragalactic radio sources. This proposal is still under consideration by NASA.

An investigation of the interaction of the solar wind with the planet Venus has been proposed for the VOIR Mission by the Laboratory for Extraterrestrial Physics of the Goddard Space Flight Center (GSFC) and the MIT Center for Space Research. The experimental part of the project consists of a microprocessor-controlled multi-mode ion and electron detector mounted on a scanning device on the VOIR spacecraft. It covers a solid angle of more than half of 4π steradians, has a time resolution of ~ 10 seconds, and can measure at both solar wind and ionospheric energies. The theoretical part of the work comprises a simulation calculation which, starting from present information available before launch, will become progressively more realistic as it incorporates the results of the measurement program. The proposed combined investigation could provide the first high-time-resolution plasma observations made on the dayside of Venus, and has the potential to increase markedly our understanding of the interaction of the solar wind with the atmospheres of unmagnetized bodies, as well as the interaction between a plasma and neutral gas. This proposal is still under consideration by NASA.

A mapping spectrometer experiment has been proposed for the Halley Comet Mission which may be launched in 1985. The purposes of the investigation are: to determine the composition and mineralogy of the comet nucleus; map the distribution of compositional units on the surface of the nucleus; detect and monitor chemical and physical activity at the surface-space interface; and map emission and reflective features in the coma and tail. In addition, several thermal emission channels will be offered to determine and map the thermal properties of the nucleus and perhaps the coma and tail. A scanning mechanism will be proposed which will allow mapping of the spectral properties in two spatial dimensions. The experiment has been proposed through the University of Hawaii and the instrument would be built under subcontract to the MIT Center for Space Research. Other participants are the US Geologic Survey (USGS), JPL, SAO, University of Washington, and Brown University.

Another proposed investigation involves an ion mass/velocity spectrometer for the Comet mission. The objectives are to study the physical and chemical processes occurring in the ionospheres of comets and to understand the processes involved in the interaction of these comets with the solar wind. The instrument sorts particles according to their mass to charge ratios, velocity, and direction using combined electrostatic and magnetostatic fields. The investigation will be under the leadership of Dr. M. Neugebauer, JPL, and MIT will supply the detectors and signal processing electronics. Other participants are Lockheed, Palo Alto Research Laboratory, and the University of Bern, Switzerland.

In a study and measurement of the elemental composition of cometary bodies two concepts are actively being pursued: 1) an X-ray fluorescent spectrometer and 2) an X-ray absorption and occultation experiment. The first is most appropriate for a flyby or rendezvous of a comet on the sunlit side. The major difficulty of the experiment is achieving adequate counting statistics with modest instrument size. It, therefore, will require rather close approaches to the comet. The second concept does not suffer from a weak source strength seen in emission, since it relies on the absorption by the comet's coma of the very strong solar spectrum as the sun is occulted by the comet. It does require that the spacecraft fly through the comet's tail to achieve the proper geometry. Because of the high fluxes, the detector can be quite small.

Our research has continued in methods of testing a possible mechanism by which variable solar activity may influence weather elements by modulating atmospheric electricity. An atmospheric electrical mechanism has been proposed by Dr. Ralph J. Markson which has become perhaps the leading contender to explain a solar-weather effect. In the suggested mechanism, variable solar activity modulates meteorological activity through atmospheric electrical processes. The mechanism postulates that solar-controlled variations in conductivity in the lower stratosphere over thunderstorms control the flow of current feeding the atmospheric electrical global circuit. This current regulates the intensity of the fair-weather electric field which, according to many theories of thunderstorm electrification, influences the charging of clouds. The latter in turn may influence cloud dynamics, changes of state of water, and rainfall, resulting in changes of latent heat released to the atmosphere and thus atmospheric circulation of small and large scales. Our proposed investigation centers on periodic measurements of ionospheric potential by lightweight instrumentation carried aloft on radiosonde balloons from a single site. If desired, the ionospheric potential can be monitored continuously by keeping the radiosonde aloft with a tethered balloon. In addition to measuring the electric field, the balloons will record the temporal and spatial variation of conductivity and ion production rate in the stratosphere.

We are continuing our studies of various concepts of a large area X-ray Timing Experiment, XTE, which meet the objectives of past proposals on the subject. Preliminary discussions have been held with the GSFC to explore possible collaborative efforts. It is anticipated that an announcement of opportunity for a future Explorer mission relating to an XTE may be released soon. Our plan is to complete our technical and organizational studies prior to the announcement so that a responsive and thorough experimental investigation can be proposed.

The primary purpose of an X-ray Timing Explorer is the study of temporal and spectral variability at ~2-30 keV, in compact galactic objects. These objects include (with some overlap) X-ray pulsars, X-ray burst sources, black hole candidates, X-ray novae, erratic X-ray variables, the "bulge" sources, and globular clusters. These studies represent a continuation of the highly successful developments in X-ray astronomy from Uhuru, OSO-7, OSO-8, Ariel-5, SAS-3, and HEAO-1. The large focusing missions, in contrast, are directed primarily toward the study of faint extragalactic objects at generally lower energies (<8 keV) and substantially lower aperture at the overlapping energies (2-8 keV). The XTE mission would combine the pointing flexibility

of an SAS-3 with the large aperture of an HEAO-1 to make possible very sensitive measurements at times and for durations which are ideally suited to the particular temporal behavior of a given source.

Two areas of interest have been identified as potential scientific investigations using the satellites of the OPEN Mission (a series of four satellites orbiting in the vicinity of earth):
1) A high time resolution 3-D solar wind plasma analyzer which will measure ions and electrons with high energy resolution. This experiment will provide the monitoring of the upstream solar wind conditions on the Interplanetary Physics Laboratory spacecraft, and provide sophisticated plasma data at 1AU. 2) An imaging X-ray detector to study the global morphology and energetics of the earth's auroral zones. This experiment would be flown on the Polar Plasma Laboratory spacecraft.

Shuttle Application Studies

Exploratory studies aimed at developing new space experiments of direct interest to the university community and applicable to the special capabilities of the Shuttle-Spacelab transportation system have been carried out and proposed to NASA. To date two have received tentative approval and are awaiting funding for a Definition Phase Study.

VLBI Station on Spacelab: Principal Investigator, Dr. B. Burke, MIT; Participants: MIT, JPL, GSFC, SAO, NEROC, NRL, NRAO.

An orbiting Very Long Baseline Interferometer (VLBI) station can be used in conjunction with existing radio telescopes on the ground to generate an effective antenna aperture slightly larger than the earth that will provide a maximum angular resolution of 0.003 arcseconds at a wavelength of 18 cm. The brightness distribution of quasars, active nuclei of radio galaxies, and interstellar OH masers will be studied with the instrument, to aid in the understanding of the unusual physical processes occurring in these objects.

The proposed station uses components and techniques that already are used extensively in VLBI observations and are adaptable readily to the Spacelab environment. The proposed experiment is complete in its own right, but the station is modular in design to facilitate the extension of capabilities for additional flights on subsequent missions. One such optional extension is the addition of a 3.8 cm receiver that would allow observation of continuum sources with a maximum angular resolution of 0.0006 arcseconds. This program has been selected by NASA to begin a Definition Phase Study in early 1980.

Hard X-Ray Diffraction Telescope (HXDT): Principal Investigator, Dr. G. Ricker, MIT.

A Hard X-Ray Diffraction Telescope (HXDT) with unprecedented sensitivity and spatial resolution in the energy range from 30-100 keV can be flown on Spacelab. In the band from 40-65 keV, the HXDT will be an order of magnitude more sensitive than the HEAO-A4 experiment. We will use this instrument to study the high energy spectra of selected extragalactic X-ray sources catalogued by HEAO-1, and to search for cyclotron lines (similar to the one found in Her X-1) and other spectral features in galactic sources. During a single Spacelab mission, we could expect to study every compact extragalactic source catalogued by HEAO-A2 (~100 objects), or detect 3-10 sources as faint as 1/3000 of the Crab (or $\sim 3 \times 10^{-7}$ ph cm² s⁻¹ keV⁻¹). These are probably the two extreme forms that an observing program might take; it is likely that we would choose some combination of the two.

THEORETICAL ASTROPHYSICS

A significant portion of our resources this year has been devoted to support of an augmented theoretical astrophysics activity within the Center. With the wealth of data now available from SAS, HEAO and other satellites as well as the ground-based observing programs, new and exciting research topics are now available which need to be investigated.

For the 1979-80 academic year, Dr. Julian Krolik has joined us as a postdoctoral research associate, and Martin Weinberg has accepted a graduate research assistantship. We hope and expect that our theoretical astrophysics effort will undergo further substantial expansion during the 1980-81 academic year. The results of the theoretical program are described in the report of the Department of Physics.

PUBLICATIONS

During the past year members of the Center contributed 35 publications.

HERBERT S. BRIDGE

Energy Laboratory

The main role of the Energy Laboratory is to encourage mission-oriented research on a broad range of energy problems through the interactive participation of people drawn from most of MIT's academic departments. The greatest single research emphasis is the efficient, economic, and socially responsible use of the increasingly "dirty" fuels of the future such as coal, tars, heavy crudes, and shale. That emphasis includes work on combustion in furnaces and engines, health effects of emissions, supply and demand studies, and conversion to clean fuels. But in addition to that emphasis, Laboratory programs include research on conservation, renewable energy sources, nuclear energy, and conventional oil and gas in both technical and economic/policy projects.

Operating expenses of the Energy Laboratory during fiscal 1980 were about \$12 million -- an increase of about 15 percent above last year. Funds to meet those 1980 expenses were provided by sponsors of research projects (65 percent by the Federal government) and by industry and foundations in grants and gifts totaling \$0.6 million. The number of faculty associated with the Laboratory during the year averaged about 45, the Laboratory professional research staff about 35, and participating students about 250. In addition, about 30 professional research staff from other MIT departments, laboratories, and centers participated in Laboratory activities.

During the past year the Energy Laboratory continued to contribute to the education of MIT's students. More than 250 graduate and undergraduate students participated in Energy Laboratory research, producing over 50 theses. Faculty and staff affiliated with the Laboratory taught 40 subjects in which they used material drawn from their Energy Laboratory research; in several cases they also used facilities developed or expanded under the auspices of the Energy Laboratory. In addition, Energy Laboratory staff members taught 10 courses during the Independent Activities Period in January 1980.

In addition to participating in MIT academic activities, Energy Laboratory researchers continue to interact closely with people and organizations outside MIT. The Energy Laboratory's three formal vehicles for such interaction -- the Center for Energy Policy Research (CEPR), the Electric Utility Program, and the Advanced System for Process Engineering (ASPEN) -- have continued to grow.

The CEPR has continued to add to its list of Associates, which includes organizations from both the private and nongovernmental public sectors that participate in CEPR research projects and provide financial support appropriate to their resources. In the past year five organizations -- including two from foreign countries -- joined the Associates program, bringing the total membership to 30. The CEPR held two major meetings during the year. The first, held in November 1979, focused on the world oil situation, and the relationship between energy prices, inflation, and economic activity. The second, held in May 1980, considered the short-run world oil situation. Each meeting brought together representatives from government, industry, labor, universities, and public interest groups.

Nine utilities have been participating in the 1980 Electric Utility Research Seminar and Workshop Program -- the major activity within the Electric Utility Program of the Laboratory. Workshops in the past year have considered coal utilization; environmental management, electric power systems, and end use technology; and nuclear engineering. At these workshops utility representatives exchanged ideas with MIT personnel involved in research relevant to utility needs. More than a dozen projects received support as a result of the workshops.

After three years' work, Energy Laboratory researchers have begun to test ASPEN in industry. More than 40 major companies will be using ASPEN on a trial basis during the next two years as they develop and modify their industrial processes. As a result of this program the researchers will be able to improve ASPEN in response to industrial needs.

In addition to those formal programs, Energy Laboratory researchers participated in the US/USSR Cooperative MHD program. Central to that program is the U-25B MHD facility, which is located at the High Temperature Institute in Moscow and which uses a unique US-built 5-Tesla superconducting magnet in conjunction with a Soviet MHD channel. Energy Laboratory personnel have participated in all experiments with the facility and have provided considerable support in the areas of experimental planning and performance evaluation, and most recently in the area of diagnostic measurements.

Increasing activity in the area of energy model analysis has led to the establishment of a new formal Laboratory program area. Energy models are becoming more and more important for evaluating alternative energy policies; consequently, those models should be analyzed to determine their validity and applicability in studies of specific policy issues. Researchers in the Laboratory's new Energy Model Analysis program are developing and applying formal procedures for conducting such model analyses. They have already completed analyses of several models and have recently initiated a three-year program of additional analyses and methodological research.

Phase II of the Combustion Research Facility construction program began during the past year. A handling, storage, and feed system for pulverized coal has been designed and is now being constructed.

Construction of the Energy Laboratory's multi-user laser facility is now under way. When completed the laser facility will provide a highly directed source of heat for research on materials and materials processing. The facility will later be expanded to include chambers and optical systems designed for research on welding, cutting, scribing, and surface heat treatment, and on other topics such as coal volatilization.

The summaries that follow describe many of the active Energy Laboratory projects during the past year. Although most projects involve research teams consisting of faculty, staff, and students, only principal investigators are mentioned by name because of space limitations. The project descriptions are organized according to the current Laboratory administrative structure.

Energy System Modeling and Analysis

Professor Robert Pindyck of the Sloan School of Management is undertaking research to study the linkages between exploration and production of nonrenewable resources, examine the characteristics of optimal exploration patterns, consider the effects of various uncertainties on resource exploration and production, analyze and design government policies affecting natural resource markets, and model the behavior of international resource markets.

Professor Daniel McFadden of the Department of Economics and Dr. Knut Mork of the Energy Laboratory are conducting an integrated analysis of the overall economic effects of changes in energy prices. Aspects included are inflation, fluctuations in employment and economic activity, and changes in the energy-GNP ratio. The project includes an analysis of the 1974-75 recession as well as more current events.

Dr. Mork and David Wood of the Energy Laboratory and the Sloan School of Management are leading an analysis of technology choice, energy conservation, and other issues relevant to the future of the world aluminum industry. Special attention is being given to the economic significance of new and emerging technologies. Other topics include the international location of the

industry, its competitive structure, and the future of the bauxite cartel.

Dr. James Gruhl of the Energy Laboratory and Professor Fred Schweppe of the Department of Electrical Engineering and Computer Science are leading an effort that takes advantage of an extensive air quality monitoring network and previous air pollution dispersion modeling in the Chestnut Ridge area of Pennsylvania. Their major task is to establish, through several distinct epidemiological approaches, health data to be used to test hypotheses about relations of air pollution exposures to morbidity and mortality rates in this region. Another important goal of their research is to collect and test the many available models for associating health effects with air pollution to determine their predictive validity and their usefulness in the choice of siting future energy facilities.

Jacqueline Carson and Dr. Supriya Lahiri of the Energy Laboratory are undertaking an effort to maintain and make available important energy models and data bases developed in Energy Laboratory research projects.

Dr. James Smith of the Energy Laboratory is developing methods to estimate the supply function and future availability of depletable fuel resources -- oil and gas. His analysis is concerned with all three phases of the mineral supply process: exploration, development, and production. The dynamic influence of resource depletion on marginal costs is of primary interest.

Energy Model Analysis

For the past three years, the Energy Laboratory's Energy Model Analysis Program (EMAP) -- recently made a formal program area -- has undertaken the assessment of several nationally important energy policy models. Led by Mr. Wood and Dr. Gruhl, those assessments have included in-depth analyses of the accuracy of the computerized implementations, the validity of data and structures, the appropriateness of model documentation, and the evaluation of model operating characteristics. Approximately five more energy policy models will be assessed as part of this project.

EMAP is also assessing a new adaptation of the Utility Simulation Model (USM) of Teknekron, Inc. The model, originally designed for nationwide studies, is now being made applicable to the economic and environmental issues of specific electric utilities. The assessment of this adaptation will be conducted in parallel with the development activities -- a type of approach that is being tried here for the first time.

Dr. Smith is performing a comparative evaluation of the performance of statistical methods for forecasting petroleum discoveries. Forecasting methods developed at MIT are compared to alternative techniques developed and applied within the British Petroleum Company.

INTERNATIONAL ENERGY STUDIES

Dr. Thomas Neff of the Energy Laboratory and Professor Henry Jacoby of the Sloan School of Management are conducting an analysis of the international market in uranium. This analysis includes the influence of industrial and governmental structures on producer and consumer sides, supply and demand trends, and international trade flows. Implications for price and security of supply are also included in this analysis.

Dr. Neff and Professor Morris A. Adelman of the Department of Economics are evaluating the recent rapid changes in the world oil market structure and the implications for price, price stability, producer behavior, security of supply, relations between consumer nations, and other issues. This developmental effort is intended to establish the groundwork for future research efforts.

Dr. Neff is conducting a review of problems of energy development in developing countries to evaluate research programmatic opportunities in this area. Attention focuses on domestic and international economic issues arising from rising energy prices, the institutional difficulties

created, relationships between long- and short-run energy and development decisions, and the energy planning opportunities afforded by new technologies and energy management approaches.

Professors Adelman, Jacoby, and Pindyck are conducting extensive research into the world oil market to develop improved methods and data and a better understanding of the market's characteristics. Included are a study of the OPEC cartel, forecasts of future world oil prices, analysis of consumer- and producer-country policies, study of trade patterns in oil, and analysis and potential financial problems created by changes in oil price and volume. Several supporting economic models have been developed.

Utility Systems

Dr. Richard Tabors of the Energy Laboratory and the Department of Urban Studies and Planning, Professor Gary Lillien of the Sloan School of Management, and Dr. Raymond Hartman of the Energy Laboratory are analyzing the markets for photovoltaic energy systems. The major objectives of this project are to study the interface between photovoltaic systems and utilities, to study relevant rate regulation concerning rates for photovoltaic systems, and to develop market models for estimating the evolving demand for photovoltaics. Major accomplishments during the past year include development of a model for solar flux to be used as an input to models of photovoltaic systems performance, development of a model of electric rate-setting, further development and testing of a market diffusion model for photovoltaic market penetration, studies on capital availability for photovoltaics and the need for standards and warranties for photovoltaics, and study of appliance efficiency standards and their implications for future electric demand.

Dr. Tabors and Professor Schweppe are developing an electric generation expansion analysis system (EGEAS) to analyze the effect on expansion plans of rate structure changes, load management techniques, cogeneration, new energy technologies, alternative configurations of transmission and distribution, and interconnections between major utility systems.

Dr. Gruhl is developing a computerized tool to predict emissions, air ambient pollution concentrations, and health effect levels from any combination of: fuel types and sources, pretreating equipment, generation equipment, abatement equipment, site types for different dispersive potentials and population densities, and available health effects models.

Dr. Tabors conducted a worth analysis for an advanced flywheel storage concept for tandem operation with photovoltaics that are currently being developed by MIT Lincoln Laboratory. The applications he examined were a single-family residence and a multi-family load center. The objectives were to determine optimal flywheel sizing for the various operating environments and to determine the financial parameters that would affect market penetration. The operating modes included both utility interface and remote, stand-alone logics.

Professor Schweppe and Dr. Tabors have developed techniques for forecasting industrial and commercial customer cogeneration within a single utility. This has not only yielded methods for forecasting but has also provided more insight into the combined economic impact of regular electricity rates and cogeneration rates upon customers and the utility. Data from the New England Electric System service area were used to estimate the local potential for cogeneration along with its revenue and cost effects and to highlight aspects requiring further research.

Professor David White and Dr. Burton Pierce of the Energy Laboratory and Professor Schweppe have performed an assessment of the fuel strategy proposed by Consolidated Edison Company of New York, Inc. (Con Edison) for meeting their electrical and steam demand, and development of alternative strategies. The project focus is on definition of technological, economic, and regulatory trends to permit proper perspective on Con Edison's early 1980s decisions as seen over a longer planning horizon. The outcome of this research project will be quantification and analysis of the trade-offs that warrant consideration in choosing Con Edison's fuel strategy for the 1980s.

Dr. Tabors is performing analyses useful to the US Department of Energy's residential portion of its Photovoltaics Program. The project has four major goals: 1) to analyze existing regional housing stock models and specify a regional housing model for photovoltaics; 2) to conduct a preliminary analysis of the roof area available for the retrofit of photovoltaic power systems on

residences; 3) to develop the sampling methodology and baseline survey for the market analysis portion of the photovoltaic residential experiments to be undertaken in 1980 and 1981; and 4) to revise the market development portion of the residential implementation plan for photovoltaics.

Center for Energy Policy Research and Other Policy Studies

Professor Jeremy Shapiro of the Sloan School of Management is investigating the use of mathematical programming models and methods, especially decomposition techniques, in the analysis of energy planning problems. Specific topics include: integration of mathematical programming process models with econometric models; derivation of derived demand curves for energy commodities with applications to coal; derived demand curves and capacity planning under uncertainty; and integration of coal supply and utility demand models.

Professor White led a recently completed study that prepared a sample set of cost comparisons for typical grass-roots industrial boiler systems and used those comparisons, together with environmental and regulatory considerations, to examine alternative industrial steam generation systems. Recognizing geographical diversity of fuel costs, comparisons were made on a regional basis.

Professor Ben Ball of the Sloan School of Management is developing an understanding of the character of the interactive forces at work between various types of exploring organizations and the petroleum-importing developing countries.

Professor Pindyck is investigating the desirability of government participation in development of new nonconventional energy supplies. Of particular concern is an evaluation of possible sources of market failure, and the likely efficacy of government subsidies to correct the effects of that market failure. Emphasis is on designing government policy for new energy technologies.

Dr. Malcolm Weiss of the Energy Laboratory recently completed a study that estimated whether improved technology might significantly reduce unit costs for production of shale oil in a planned large-scale industry as contrasted to the case usually contemplated -- a small industry evolving slowly on a project-by-project basis.

Dr. Guy Burgess of the Energy Laboratory has been researching the governmental energy decision-making process, in which a practical process for diagnosing and correcting major decision-making problems is being developed. His goal is to select mechanisms that would enable decision makers to make decisions that are more rational and equitable, yet less subject to polarization and excessive delay.

Professor Ted Greenwood of the Department of Political Science is identifying and analyzing important Congressional votes on controversial energy policy issues since 1973. He is attempting to explain Congressional voting behavior on the basis of economic interests of the Congressman's home states, and other more ideological variables.

Professor Pindyck is conducting an analysis of the effects of price controls and regulatory uncertainty on the exploration and production of oil and other resources. He is also investigating optimal subsidies for synthetic fuels as a second best policy, given price controls on conventional oil.

In November 1979, Loren Cox of the Sloan School of Management moderated a conference that discussed the impact of energy price increases on inflation, recession, and economic activity in the US during the 1973-75 period. The conference was attended by a number of representatives from government, financial institutions, universities, and private companies.

In May 1980, Mr. Cox moderated the third conference devoted entirely to world oil markets, again bringing together representatives from government, financial institutions, universities, and private companies. Discussion focused on world market behavior in recent months, recent changes in world oil market structure, strains on world finance and politics, and policy responses to uncertainty.

Mr. Cox and Lindsay Wright of the Energy Laboratory are examining the implications of higher energy prices on lower income groups. Their examination has focused on developing a better understanding of the complex nature of energy-related characteristics of lower income groups, and combining these diverse but interdependent factors into a structural framework around which more effective and consistent policies can be considered.

Energy Conversion

Professor Jean Louis of the Department of Aeronautics and Astronautics is leading a research and development program in key areas of open-cycle coal-fired magnetohydrodynamic power generation. The program is divided into five sections: phenomena in MHD generators, open cycle MHD disk generator, electrode module development and testing, MHD two stage combustion kinetic modeling, and water model study.

Professor Louis and Dr. Arthur Sotak of the Energy Laboratory are developing quantitative and predictive information on the critical aspects of high-temperature industrial gas turbines in closed-loop water cooling of rotating blades, in studies on the open channel system, and in heat transfer and aerodynamic losses in air-cooled turbines.

Professor Louis is studying the use of enclosed thermosyphon loops to cool the blades of a high-temperature turbine. This shows great promise, although a basic understanding is still needed.

Professor Louis is investigating the use of lasers as a diagnostic tool for flames. This research has three separate and distinct tasks: the study of non-free radical species in hydrocarbon/air flames using the laser-induced fluorescence technique; the study of density disturbances in MHD plasmas using laser holographic/interferometric technique; and new and/or novel applications of the laser to the study of flames.

Professor Louis and Dr. Shao Tung of the Energy Laboratory are establishing a comprehensive system model that is sufficiently precise for process and engineering design optimization. Their initial model has undergone two phases of improvement. The resulting model, designated MIT-Model II, can predict a number of design and operation parameters including expanded bed height, carbon loading, and combustion efficiency. They are also establishing a data base system that will deposit all relevant data on coal-based fluidized bed combustion in a single state. This data management system is now being tested internally.

Professor Louis is analyzing test results for the U25-B MHD facility as part of the joint US/USSR Cooperative Program. Performance prediction capabilities have been improved by the development of approximate three-dimensional electrical codes. A traversing pitot-static and light intensity probe has been constructed and used to measure plasma nonuniformities in the U25-B MHD facility in Moscow.

Professor Louis, in collaboration with Westinghouse Electric's Advanced Energy Systems Division, has undertaken a systems study of MHD/steam power plants using disk generators instead of the usual linear generator channels. MIT is responsible for analysis and optimization of the performance of the disk generator (both open and closed cycle), and Westinghouse integrates the MIT results into an overall systems study.

Dr. James Nash-Webber of the Energy Laboratory and Professor Louis are analyzing and predicting the detailed thermal behavior of various thermal energy storage subsystems of a 100 mW Zero-Fuel Compressed-Air Energy Storage System required by the Potomac Electric Power Company. Use of simple pebble-bed stores was shown to yield acceptable performance at low cost. The predicted thermal storage efficiency of the selected design exceeded 96 percent.

Professor Louis has led an effort in response to a Congressionally authorized attempt by the Department of Energy (DOE) to establish a network of coal research laboratories across the country. MIT and 12 other universities formed the University Coal Research Consortium of the Northeast (UCERN) and requested that the consortium be designated to operate one of DOE's coal research laboratories. Congress subsequently decided to approve funding for university coal research but not to establish a system of research laboratories. A number of research programs prepared as part of the UCERN proposal have been submitted separately to DOE for

funding. Other activities of UCERN include organizing a coal-oil mixture project involving four consortium members.

Stationary Combustion

Under the direction of Professor Janos Beér of the Department of Chemical Engineering, new measurement techniques are being developed at the Combustion Research Facility (CRF). These techniques for turbulent flame studies include a laser scattering technique capable of determining spatial and temporal distributions of soot in flames, and a laser diffraction system for determining the size distribution in drops leaving the burner. A 120 channel on-line data acquisition and data processing system has been developed for the CRF. In the second phase of its development, the CRF is equipped with pulverized coal combustion capability. A pulverized coal handling, storage and feed system has been designed and is under construction.

Professor Beér and Professor Adel Sarofim of the Department of Chemical Engineering are determining the paths and rates of transformation of fuel nitrogen in pulverized coal particles and liquid fuel droplets. By pyrolyzing coal particles and liquid fuel droplets in laminar flow reactors in closely controlled thermal and chemical environments, the time-resolved evolution of the fuel nitrogen is determined. This information is to be applied for the formation of staged combustion design strategies used to minimize the conversion of fuel nitrogen to NO_x .

Professor Louis is designing and developing (experimentally and theoretically) an ultra-high swirl, second-stage MHD combustor, which will be placed at the exit of a "conventional" MHD coal slagging gasifier first-stage combustor. The combustor is being developed in the form of a multi-annular swirl combustor having a trumpet shaped divergent nozzle exit.

Professor Sarofim and Dr. Joel Levy of the Energy Laboratory are developing models that will predict pollutant formation and destruction under fuel-rich conditions.

Professors Beér and Sarofim are determining the relationship between the air/fuel ratio and an optical property of the flame that can be used as a basis for a combustion control scheme. Spectro-radiometric studies of liquid fuel spray flames in the CRF show that a combination of the total radiation and the spectral emission from the flame front could be used to optimize combustion operating conditions with a dedicated feedback control system.

The most promising practical solution to the problem of fuel-bound nitrogen conversion to NO_x when burning high nitrogen content fuels is staged combustion. Under the direction of Professor Beér, parallel studies of computer modeling and experiments using 0.7 percent heavy fuel oil in the CRF have led to a combination of design and operating parameters that permits significant reduction of NO_x emission without excessive emission of soot.

Professor Beér is performing experiments on turbulent diffusion flames and pyrolyzing droplet streams of SRCII fuels using the CRF and a laminar flow laboratory reactor, respectively, to examine the response of the fuel nitrogen conversion and carbon emission processes in SRCII fuels to controls by staged combustion. Initial results show that significant reduction in NO_x emission can be achieved without excessive amounts of soot emission by the suitable combination of parameters such as the first stage air/fuel ratio, temperature, droplet size distribution and residence time, and a tightly controlled introduction of the rest of the combustion air into the second stage of the combustor.

Professor Beér and Dr. Malcolm Jacques of the Energy Laboratory are performing experiments using shale in laboratory-scale reactors, and in the 0.6 x 0.6 m Fluidized Combustion Research Facility, to determine fundamental pyrolysis and combustion parameters of shale. The information obtained from these experiments will be used for the development of combustion modifications that will permit the reduction of NO_x emission and the economic utilization of this high nitrogen content fuel.

Professor Sarofim is measuring the concentration profiles and radiation from flames burning fuel rich. The measurements he obtains will enable him to develop control strategies for reducing NO_x emissions from combustors fired with coal- and shale-derived fuels.

Professors Jack Howard and John Longwell of the Department of Chemical Engineering are performing studies of the diffusion of flame intermediates to cold surfaces; deposit-forming reactions will provide basic information on related internal combustion engine deposits. This work makes use of a molecular beam system for detailed analysis of both stable and unstable flame species.

Professor Beér is studying the paths of transformation of coal-nitrogen to NO_x and N_2 in the fluidized combustion process with the aim of identifying steps that lead to the destruction of NO . The research has focused on the heterogeneous reaction between NO and solid carbonaceous particles; kinetic parameters have been determined for this reaction and design, and operating conditions have been identified that lead to reduced NO_x emission from coal-burning fluidized combustors.

Professors Sarofim and Longwell are studying the interaction of sulfur with mineral constituents in coal. This may provide an alternative to flue gas treatment for controlling the emissions of sulfur oxides to the atmosphere.

Professors Sarofim and Longwell are also studying the kinetics of reactions of fixed nitrogen species with soot. An understanding of these reactions is expected to lead to improved control technology for NO_x emission. They also are characterizing the gasification reactions of char under fuel-rich conditions. Their investigation will provide data required for the design of staged combustors.

The nitrogen oxides formed in fluidized coal combustors can react with solid carbon in the bed with the effect of significantly reducing the emission of NO_x . The carbon concentration in the fluidized bed necessary for this reaction is dependent on other fluidized combustion operating parameters, mainly the bed temperature and the oxygen concentration in the flue gas. Professor Beér is conducting experiments aimed at determining the relationships between FBC operating variables and carbon load on one hand, and between the carbon load, combustion and NO_x emission on the other. The results are used for both combustion process optimization and for the rigorous testing and further development of the MIT Fluidized Combustion Mathematical Model.

Transportation Propulsion

Dr. Joe Rife of the Department of Mechanical Engineering and the Energy Laboratory is performing single cylinder engine experiments and analyses to develop a method for including knock in the engine cycle calculations. Current thermodynamic models of engine cycles do not include knock.

Dr. Rife and Dr. David Hault of the Department of Mechanical Engineering are examining factors that govern the turbulent flow field inside a spark-ignition cylinder, and are performing fundamental experiments to test the application of the rapid distortion theory in a cylindrical pie shaped bomb.

Professors John Heywood and James Keck of the Department of Mechanical Engineering and Dr. Rife are developing fundamental information on the processes that control the formation of hydrocarbons in the combustion chamber, the flow of hydrocarbons into the exhaust, and the degree to which they can be oxidized in the exhaust system.

Professor Stephen Pope is developing a numerical model to calculate the properties of turbulent flows with combustion. In particular, the model accounts for the interaction between turbulence and chemical reaction. The results of calculations using the model compare well with measurements for a chemically reacting turbulent mixing layer.

Drs. Hault and Rife are performing studies to define the amount of soot that is formed with fuels of various constituents. Kerosene doped with various additives was used as test fuel. The result of adding these compounds was to change the hydrogen-to-carbon ratio of the fuel from that of standard aviation kerosene to that of more highly aromatic fuels.

Dr. Rife and Professor Heywood are exploring the processes that control formation and burnup of particulates in a typical automotive diesel engine. Their work includes development of a

computational model of the engine, performance of engine and burner experiments, and characterization of particulates collected from those experiments.

Dr. Agop Ekchian of the Department of Mechanical Engineering, Professor Heywood, and Dr. Rife are leading a research effort to extend and refine an existing MIT cycle simulation program for a direct injection stratified charge engine. Their program will then be used in a detailed investigation of heat release and emission characteristics of this engine. Special emphasis will be placed on developing effective models for the formation of unburned hydrocarbons during the combustion process.

Fuel Conversion and Health Effects

Professor Charles Satterfield of the Department of Chemical Engineering is developing a quantitative understanding of the effects on reaction rate and selectivity of the interplay between intrinsic kinetics and mass transfer in a slurry-bed reactor for Fischer-Tropsch synthesis.

Professor Jeffrey Steinfeld of the Department of Chemistry is applying laser-induced fluorescence excitation spectroscopy to monitoring the formation and release of polynuclear aromatic hydrocarbons from fossil fuel combustion. One of the principal issues addressed in the development of control strategies for carcinogens in the environment is the development of a method that can detect these species at their source or in ambient levels.

Professor Howard and Dr. William Peters of the Energy Laboratory are conducting basic studies of coal pyrolysis and hydrolysis. The specific objectives of their research are: to identify the optimum conditions of temperature, hydrogen pressure, and particle size for achieving highest yields of desired products; to clarify the role of secondary reactions of volatiles within and outside the decomposing coal particles; and to assess the catalytic and other chemical effects of the inherent coal mineral matter and of low-cost additives on rapid pyrolysis and hydrolysis.

Professors Howard and Longwell and Dr. Peters are establishing fundamental data bases and kinetic models of the pyrolysis behavior of biomass of potential commercial importance in the United States. Effects of reaction conditions of practical interest including temperature, residence time, and heating rate on yields and compositions of product gases, liquids, and char are measured. The ability to predict the pyrolysis behavior of wood from a knowledge of the corresponding behavior of its primary constituents is also under investigation. Ultimate benefits of the program will include better quantitative data on the kinds and amounts of liquids that might be obtained from biomass pyrolysis and an indication of what operating conditions offer the most commercial promise for conversion of different biomass materials to useful fuels and/or chemical feedstocks.

Professor Satterfield is extending previous studies of catalytic hydrodenitrogenation reaction in the vapor phase to the liquid phase. Model compounds representative of those found in synthetic liquid fuels from coal, oil shale, and tar sands will be studied in a highly instrumented laboratory-scale trickle bed reactor which is now under construction. The system has been carefully designed to be capable of providing intrinsic kinetic data under pressure and temperature conditions representative of industrial processes.

Professor Longwell is determining the effects of dolomite solids on the pyrolysis behavior of coal. Results to date indicate that pyrolysis of coal in the presence of calcined dolomitic stones furnishes essentially sulfur-free product gases that have increased heating value and that account for more of the initial energy of the coal than the gas formed in the absence of the solids. Liquid yields are somewhat reduced by the stones but their quality is modestly improved. Preliminary economic analyses based on the data obtained in this program indicate that this approach to coal processing offers one of the lowest cost routes to generating storable gaseous and liquid fuels from coal. Potential applications in the electric utility and large-scale industrial energy utilization sectors are recognized.

Professors Howard and Longwell and Dr. Peters are assessing the potential for extending US supplies of high-quality liquid fuels through processes based on thermal degradation of domestically obtainable biomass. The work examines the feasibility of obtaining commercially interesting quantities of substitute high-octane motor fuels, distillate fuels, and heating oils,

including -- but not limited to -- alcohols, by pyrolysis of biomass-related materials such as pure cellulose and wood. Total liquid yields and compositions of selected fractions are measured as a function of temperature, residence time, and other operating conditions of practical interest. Preliminary results indicate that yields of valuable light oxygenated liquids of up to 10 wt percent of the dry feed might be obtained by pyrolysis of sweet gum hardwood through proper selection of reaction conditions.

Professors Longwell and Sarofim are studying the reactions of the various nitrogen species in fuel-rich combustion. These studies are carried out under sooting conditions to establish the rates of conversion of these nitrogen species to molecular nitrogen.

Professor Sallie Chisholm of the Department of Civil Engineering is performing physiological and environmental studies of the lipids in over 30 species of fast-growing microalgae. The ultimate goal of large-scale culture for oil production and sewage treatment, the rate of production of oil in these organisms was determined as a function of nutrient concentration, temperature, light, and trace metal concentration. A production rate of 160 bbl of oil per hectare per year is projected.

Professor Sarofim is studying the formation of polycyclic aromatic hydrocarbons during the combustion of coal and synthetic fuels.

Professors Longwell and Howard are conducting a study that addresses chemistry questions in the formation of soot and polycyclic aromatic hydrocarbons from the combustion of fuels that may readily be vaporized.

Professor Beér is identifying polycyclic aromatic hydrocarbons in turbulent flames of coal, petroleum, and synthetic fuels, and in coal-burning fluidized combustors to determine the conditions under which they form or are destroyed. Diagnostic tools have been developed for *in situ* soot concentration measurement and for the sampling of polycyclic aromatic hydrocarbons in flames and fluidized combustors. The main polycyclic aromatic hydrocarbons have been identified. Experiments continue to follow the paths of polycyclic aromatic hydrocarbon formation and destruction in petroleum, coal-derived liquid and coal-oil mixture flames, and in fluidized coal combustion.

Professor Longwell is collecting samples of organic particulates from full-scale combustion equipment to determine the molecular composition of extractable material and to ascertain the mutagenic activity of that material.

Process Modeling

Under the direction of Professor Lawrence Evans of the Department of Chemical Engineering an advanced computing system for chemical process engineering has been developed. ASPEN (Advanced System for Process Engineering), a software system, has been assembled to meet the need in the 1980s for designing large fossil fuel conversion plants. The ASPEN project is currently in its second phase, which includes testing and debugging the system, developing enhancements and training materials, and making the system available for use by the Department of Energy and industry.

Advanced Technology

Drs. John Haggerty and W. Roger Cannon of the Energy Laboratory are exploring ways of producing ideal powders, both for studying the fundamentals of the production processes and for improving the properties of resulting refractory ceramic parts. Silicon nitride (Si_3N_4) has been selected as the primary study material because of its technological importance for use in ceramic turbines and engine parts.

Dr. Haggerty is conducting basic materials science and materials processing research with the objective of developing processing means and glass compositions that will result in broad-band anti-reflective coatings of glass. The ultimate use of treated glass sheets is intended primarily for covers of flat plate solar collectors; anti-reflective coatings increase the extractable heat 30-50 percent under most solar-flux and ambient conditions.

Dr. Haggerty and Professor David Adler of the Department of Electrical Engineering and Computer Science are studying means to saturate valence alternation pairs in chalcogenide glass semiconductors. This will permit the Fermi level to be unpinned and will eliminate trap-limited mobilities. These materials are being considered for low-cost solar cell applications.

Professor H. Kent Bowen of the Department of Materials Science and Engineering is leading a program to establish a scientific base for electrochemistry in three areas: use of electrolytes to study reactions on surfaces (electrocatalysis); fabrication studies of the Na-ion electrolyte, $\text{Na}_3\text{Si}_2\text{Zr}_2\text{PO}_{12}$; and the electrowinning processes for more efficient metals processing.

Dr. Leon Glicksman of the Department of Mechanical Engineering is directing a program of advanced technology for energy conservation. Initial work has focused on advanced building technology, and research on the fundamentals of thermal insulation has begun.

Dr. Glicksman is developing limiting-order-of-magnitude models to understand the thermal performance and aging of closed cell urethane foam insulation. This insulation has the highest resistance per inch of any insulation available for home construction and appliances.

Dr. Haggerty is directing the development of a unique laser-heated crystal growth facility which will be operational by August 1980. This facility, which will permit the growth of extremely high purity, high melting point crystals with virtually complete freedom to select ambient atmospheres, will be used to supply crystals for materials research programs. It will also be used for rapid quenching, melting point determination, high temperature thermal gravimetric analysis, and synthesis experiments.

Dr. Haggerty and Dr. Stephen Danforth of the Energy Laboratory are developing a new process to produce high efficiency, large-grained polycrystalline thin film silicon photovoltaics. In this process, a thin amorphous Si film, deposited on a suitable substrate, is crystallized in a controlled manner at specific locations using a laser. Subsequent annealing causes these crystallites to grow to impingement with the resulting grain size to film thickness ratio >10 .

Professor Adler is fabricating solar cells employing low-cost chalcogenide glasses in several different configurations. Heterojunction cells employing an upper layer of amorphous selenium have proved to be the most promising. Heterojunctions between amorphous selenium and amorphous silicon-based alloys are also being investigated.

Nuclear

Professor Michael Driscoll of the Department of Nuclear Engineering is conducting an evaluation of the cost of recovering uranium from seawater using state-of-the-art adsorbers and advanced ion exchange materials. If his project goals can be realized, enough uranium will be available to sustain thousands of light-water reactors for thousands of years without resorting to fuel reprocessing or breeder reactors, and with an order of magnitude reduction in the environmental impact of the nuclear fuel cycle.

Dr. William Hinkle of the Energy Laboratory, Professor Peter Griffith of the Department of Mechanical Engineering, and Professors Mujid Kazimi and Neil Todreas of the Department of Nuclear Engineering are developing multidimensional computer codes that can be used for the analysis of subassembly voiding incoherence under postulated accident conditions in the Liquid Metal Fast Breeder Reactor. Two codes are being developed in parallel. One will use a two-fluid (six equation) model and the other a mixture (three equation) model. The code development has been supplemented by a recently completed experimental study of flow oscillations under low flow, low power conditions.

Professor Kazimi and Professor Allan Henry of the Department of Nuclear Engineering are improving and demonstrating the capabilities of the transient analysis of the code THERMIT. The code uses a three-dimensional, two-fluid, two-phase flow model and has an advanced heat transfer package. Those features allow THERMIT to perform reactor core thermal-hydraulic analysis for severe transients.

Dr. Hinkle recently completed a project that extended earlier research concentrating on assessment of the capabilities of the code COBRA-IIIC/MIT. Improvements have been made in the areas of thermal coupling of fuel pin to coolant, heat transfer logic, two-phase mixing, transverse momentum coupling and critical heat flux correlations. The improved code has been applied to the analysis of two transients typically analyzed as part of safety evaluations of pressurized water reactors and boiling water reactors. Professor Norman Rasmussen of the Department of Nuclear Engineering and Dr. Marvin Miller of the Energy Laboratory are investigating technical and institutional measures that will permit the orderly expansion of nuclear power worldwide while minimizing the occurrence of nuclear weapons proliferation. Of special interest are the implications of the implementation of so-called "sensitive" nuclear technologies, i.e., uranium enrichment, fuel reprocessing, and heavy water production in non-nuclear weapons states.

Professor Rasmussen has developed calculational methods for determining the time unavailability of systems. The present code couples the BIT code with the FRANTIC code so the input can be the system fault tree. This permits optimization of system test interval. The code LIMIT has recently been coupled with the BIT-FRANTIC code to permit a Monte Carlo simulation of error spread.

Professor Rasmussen has developed the code packages MOCUS-BACFIRE and MODCUT-BACFIRE to identify, directly from the system fault tree, a set of cutsets that are common cause failure candidates.

Professor Driscoll and Professor David Lanning of the Department of Nuclear Engineering are improving the Pressurized Water Reactor (PWR) core designs and fuel management strategies to increase uranium utilization in the once-through fuel cycle. Their emphasis has been on the development and application of consistent methods for evaluating the many innovations suggested.

Professors Lanning and Todreas are developing a detailed model of a PWR steam generator to study the operation of the generator with emphasis on the secondary side. A three-dimensional fluid thermal hydraulics model utilizing a homogeneous two-phase flow representation will be used. The entire steam generator, primary and secondary systems, will be modeled from inlet to outlet.

Environmental Management

Dr. E. Eric Adams of the Energy Laboratory is determining the external fluid mechanics of ocean thermal power plants using experimentation and mathematical modeling. The experimental program is aimed at the simulation of ocean thermal energy conversion (OTEC) operation (recirculation and environmental impact) under schematic, but realistic, oceanographic and plant design conditions. Laboratory results are being used for verification and calibration of mathematical models of OTEC operation.

Professors Michael Golay and Sow-Hsin Chen of the Department of Nuclear Engineering and Dr. Frederick Best of the Energy Laboratory are improving the existing Drift Elimination Wind Tunnel and are developing a laboratory-standard drift measurement method in preparation for a competition among various proponents of field measurement methods for cooling tower drift eliminator performance.

Professor Golay has developed a numerical simulation model of atmospheric plumes and is currently improving and verifying the model for a broader range of applications. The model employs a mixed Eulerian-Lagrangian finite-difference simulation of plume rise, advection, and atmospheric turbulent diffusion with pollutant transport and reactions being treated with detailed space and time dependence. Applications are in point-source air pollution transport modeling, notably for electric power plants, cooling towers, and nuclear plant accidents.

Dr. Adams and Professor Keith Stolzenbach of the Department of Civil Engineering are adapting existing finite-element models of far field circulation and dispersion to include better representation of the near field. Rather than modeling the near field numerically, the mass, momentum, and thermal energy entering and leaving the near field are prescribed as time-varying boundary conditions based on results of analytical or experimental model studies.

Professor Rafael Bras of the Department of Civil Engineering is using Model Output Statistics forecasts produced by the National Weather Service to help develop a computer program to investigate the value of various nonlinear terms which, it is hoped, will improve short-term weather prediction ability. Knowledge of future weather conditions can be used to optimize weather-related operations of power plants and power systems.

Professor Bras and Professor Daniele Veneziano of the Department of Civil Engineering are extending and modifying probabilistic models of mineral exploration to correct existing inadequacies. Their work will provide better and more accurate inference algorithms and sampling exploration programs that will result in improved assessment of mineral resources.

Professor Donald Harleman of the Department of Civil Engineering and Dr. Adams are identifying and evaluating the potential cooling system designs used in western energy development. For each design, appropriate on-site storage capacity and water allocation is considered. Systems are evaluated in terms of cost to the energy producer and the expected conflict with other water users. Evaluation is being performed in the context of a case study involving the Power River Basin in Wyoming.

Professor Harleman and Dr. Adams are assessing model formulations for hydrothermal circulation and evaporative heat and mass transfer within cooling ponds by comparing detailed field measurements. Their assessment will serve as a model calibration and will help guide future field measurement studies.

Professor Harleman and Dr. Adams also are attempting to improve the performance and operation of various ash and slurry ponds that are used to dispose of liquid wastes from fossil fuel power plants. They are seeking improvements through formulation of comprehensive mathematical models that combine descriptions of hydrodynamic transport with biogeochemical transformations including precipitation, bottom sediment interaction, and resuspension.

DAVID C. WHITE

Laboratory for Nuclear Science

The LNS provides support for research by faculty and research staff members primarily in the fields of basic nuclear and elementary particle physics, including the activities of the Center for Theoretical Physics in these fields. It also supports some projects involving application to other fields of experimental techniques developed in its primary activities and provides a computing facility for its program. This facility is shared by some activities of the Center for Space Research, the Energy Laboratory, and others. The primary experimental programs are in three areas: the largest effort is in intermediate energy nuclear physics, centered at the Bates Linear Accelerator in Middleton, Massachusetts. The second area is high-energy physics, with major projects at Fermi National Accelerator Laboratory (FNAL) in Batavia, Illinois; at the European Center for Nuclear Research (CERN) in Geneva, Switzerland; and at the German Electron Synchrotron Laboratory (DESY) in Hamburg, Germany. The third field is heavy ion physics with activities at Brookhaven National Laboratory (BNL) and Lawrence Berkeley Laboratory (LBL).

Intermediate Energy Nuclear Physics

The principal activity in this field is centered at the Bates Linear Accelerator, which functions under the direction of Professor Peter T. Demos. This accelerator has become the national facility for intermediate energy electron physics where a major experimental program to study the properties of the atomic nucleus, using intermediate energy electrons and photons to generate a wide variety of reactions, is under way. MIT faculty and Bates staff physicists, and some 80 user physicists from 29 other universities and laboratories in the US, Canada, and Europe, are presently engaged as initiators or collaborators in experiments there. Twenty MIT graduate

students were associated during the past year with the intermediate energy nuclear physics programs.

The intermediate energy program at MIT continues to center about electron scattering experiments using the Bates high-precision electron scattering spectrometer. This unique spectroscopic facility is being applied intensively to a majority of the more than 40 experiments authorized for performance at Bates. The other experiments are directed primarily to studies of photon-induced pion and proton-emitting reactions. The latter are also important forerunners of the experimental programs planned for the Laboratory's new large experimental hall, and its associated facilities, which are now nearing completion and expected to be in active use by early 1981.

Further developments which will extend both the accelerator's research domain and, together with the new experimental hall, its ability to meet the increasing requirements of users, are in progress. Construction funds for a beam recirculation system, which will increase the maximum beam energy to 750 MeV, have been approved. The required building modifications and tunnel construction will begin during the fall of 1980, and the project is scheduled for completion in 1982. Development of a polarized electron beam source has continued (in collaboration with Yale University physicists). This will open a new area of experimental investigation.

Another group in intermediate energy nuclear physics is collaborating with physicists at the BNL in the study of hypernuclei using a separated K meson beam in order to investigate the binding of lambda particles in nuclear matter. This group also is exploring jointly with physicists at Bell Laboratories the feasibility of constructing a detector which would measure both the flux and spectrum of low energy solar neutrinos.

Experimental High Energy Physics

During the fiscal year 1980, the Electromagnetic Interactions group completed its study of μ pair production up to the highest available invariant mass at the Intersecting Storage Ring Facility at CERN. They have continued taking data with a large detector at PETRA, the e^+e^- colliding beam device at DESY. This experiment has confirmed quantum electrodynamics down to distances of 2×10^{-16} cm; has found evidence for the existence of the gluon in three-jet events; and has measured the quark-gluon coupling constant. The group continues to search for new leptons and new particles, analogous to the J, but made of heavier quarks. Measurements will also be made of asymmetries produced by electromagnetic and weak interference in the production of μ mesons.

The Accelerator Physics Collaboration (APC) group continues its program at FNAL to study mechanisms of high energy reactions by means of a bubble chamber and other detectors. They play the leading role in a consortium of United States and European teams which exploits a "hybrid" detector system designed by them and scheduled for a major experiment to start in early 1981. During fiscal year 1980 they were engaged in the development of this system and in the evaluation of earlier experiments.

The Counter Spark Chamber (CSC) group has completed a series of experiments at FNAL utilizing the particle spectrometer developed by them, in collaboration with physicists from other institutions, to study the strong interactions of protons, pions, and kaons. These experiments have led to a definitive set of data on a wide range of reactions utilizing pure protonic targets and complex nuclei.

Over the past year the group has turned its attention to the weak interactions, and is involved in a collaborative effort to construct a major new detector for high energy neutrinos at FNAL. The initial thrust of this experiment will be the detailed study of the weak neutral currents predicted by gauge theories and discovered experimentally several years ago. Modules of the detector (which will contain 400 tons of instrumented material) are currently being tested, and the first experiment, in what should be a several-year program, will begin in 1981.

Heavy Ion Physics

The study of nuclear interactions with beams of energetic heavy ions explores the properties of nuclei which have high angular momentum and high energy and can be of species far removed from the stable nuclei found in nature. Investigations of these properties continue at BNL and LBL using newly developed tools, including a zero degree beam separator for fusion studies of exotic nuclei and a gamma-ray hodoscope for the study of high angular momenta. The group was awarded a contract from the Department of Energy (DOE) to design and construct a recoil mass selector for the Holifield Facility at the Oak Ridge National Laboratory, which they expect to use as a research tool in the future.

Applications of Nuclear Techniques

A research group, in collaboration with groups from the Harvard Medical School, the Peter Bent Brigham Hospital, and the Massachusetts General Hospital, has been applying techniques of high energy in clinical medicine. A new detector, the mesh chamber, is being developed for three-dimensional imaging of positron-emitting radioisotopes. Other projects include high pressure proportional chambers and gas scintillators for cardiac imaging and a small proportional chamber imaging system for measurements of bone mineral loss.

Another group, in collaboration with Professor Alexander Rich of the Biology Department, is developing an X-ray diffraction facility for protein crystallography based on a wire drift chamber detector originally developed at CERN. The device has been tested and is ready for application.

A scanning light ion microprobe has been developed by a member of the Heavy Ion group. It is utilized by MIT faculty in chemical engineering (studying the distribution of trace elements in coal particles), biophysics (studying the changes in the distribution of elements during cataract formation), geophysics (examining volatile trace elements in meteorites), and in nutrition (studying zinc and iron levels in control and in malnourished populations).

Particle Theory

It is presently believed that the particles which are at the basis of all matter are quarks and leptons. The quarks interact through a vector gauge field with eight internal components which are called "colors." This theory of quark interactions is called "quantum chromodynamics" or "QCD." The weak and electromagnetic interactions are also believed to be governed by a vector field which is coupled in a complex pattern to the different quarks and leptons. Both of these mathematical theories are being investigated intensively by the particle theorists. At present, all the predictions from the vector gauge theories of quarks and leptons, insofar as they have been put to direct experimental test, have been borne out.

The Particle Theory group has studied, on the one hand, the free-particle behavior of quarks in hadrons, as seen in the deep inelastic scattering of electrons and neutrinos, and on the other hand, the experimentally indicated permanent confinement of quarks in a hadron. These two aspects of properties of quarks have for years been described by two complementary phenomenological models: the parton model and the MIT bag model, respectively, which are thought to be approximations to QCD.

The simple bag model is being studied with corrections incorporating QCD effects, mainly asymptotic freedom, and the existence of a "running" (instead of fixed) coupling constant; and approaches to derive the bag model from QCD are being investigated. The continued study of the effect of multi-quark hadrons on the spherically symmetric scattering of ordinary mesons and baryons promises to lead to a rather novel interpretation of low energy scattering processes in which color plays an essential role. Investigations of a gauge invariant Hamiltonian formulation of Yang-Mills theories are also being continued.

Much work has been done on the formal mathematical properties of gauge fields, including investigations of solutions, expansion in inverse powers of the number of colors, and possible mean-field approximations.

In addition to analytical work on the solutions of classical gauge field theories and to a general examination of the symmetry properties, numerical explorations of interesting solutions are being carried out.

Nuclear Theory

The nuclear theory group has addressed a wide range of problems, including the interactions of nuclei with mesonic and electromagnetic probes, the structure of nuclei spanning the periodic table, and heavy ion reactions from below the Coulomb barrier to relativistic energies.

A substantial theoretical effort directed at a microscopic understanding of nuclear static and transition densities has been motivated by the high precision electron scattering experiments performed at the Bates Accelerator.

Significant progress was made in nuclear many body theory and the time dependent theory of nuclear dynamics.

A variety of projects are being pursued involving a QCD description of hadrons and the forces between them within the context of the MIT bag model. One of the interesting results of this program is that massive nuclei-sized multi-quark states that possess high strangeness may be metastable.

Pion nucleus elastic scattering is being studied in terms of isobar-nucleon hole collective doorway states, with a complex isobar-nucleus interaction potential playing a central role.

A general theory of the role of final state fluctuations in two-step nuclear reactions through doorways has been formulated and investigated.

A continuing program of interrelating semi-leptonic weak and electromagnetic interactions is being pursued.

Summary of Support

Participants in the various research programs during the past year amounted to approximately 470 people. This includes 55 academic staff members, 81 graduate students, and at least 81 undergraduates from MIT and other institutions. The latter were involved in senior theses, Undergraduate Research Opportunities Programs, work-study, and similar programs. There were 80 research staff members with Ph.D.s, including visitors and guests, and 175 employees in supporting categories such as engineers, technicians, machinists, and computing and administrative personnel. More than 80 active user physicists from some 29 institutions participated in the program at the Bates Linear Accelerator. At least seventeen Ph.D.s, four S.M.s and six S.B.s were awarded based on thesis research within LNS.

Support during fiscal year 1980 from the contract with DOE is expected to total \$14,223,000. This represents an increase of about 13 percent over the preceding year. This sum breaks down as follows: operations costs (salaries, wages, materials, services, travel, and overhead) were \$10,020,000; of this \$3,480,000 was for experimental and theoretical high energy physics, \$5,125,000 was for intermediate nuclear energy physics for the support of the Bates Linear facility, and \$1,415,000 was for nuclear structure theory, solar neutrino, and heavy ion experiments. Equipment costs totaled \$2,303,000; of this \$753,000 was for high energy physics and \$1,550,000 was for medium energy and heavy ion physics. A total of \$100,000 will be expended for general plant projects associated with the Bates Linear Accelerator. An additional \$1,800,000 has been supplied to Bates for a recirculator construction project which upon completion will permit a doubling of the energy of the Bates Linac. Support for relatively new Laboratory programs relating to the application of high-energy techniques to medical and biological problems totaled some \$454,000 (support came from the National Institutes of Health, the National Science Foundation, the MIT Whitaker Fund, and DOE). Support for other programs within LNS including support from other institutions and laboratories for collaborative work

undertaken directly by LNS totaled about \$49,000. The Cabot Fund granted \$300,000 to the laboratory, of which \$100,000 was for the support of the Center for Theoretical Physics. The Sloan Fund provided \$100,000 support for High Energy Physics research.

JEROME I. FRIEDMAN

Nuclear Reactor Laboratory

Research utilization of the MIT Research Reactor (MITR-II) continued at a strong level. The number of irradiations increased significantly over the previous year. A wide variety of research programs in neutron scattering, nuclear materials, radiochemistry, trace analysis, reactor engineering, and nuclear medicine were carried on. The fractional use of the reactor for research, as opposed to service, was increased. Several new research thrust areas were defined and activities were initiated to increase future utilization of the Nuclear Reactor Laboratory (NRL) facilities, especially the MITR-II. Another year of routine, safe, and efficient operation was completed with the research reactor. The net cost of reactor operation was maintained close to budget estimates, and the favorable ten-to-one ratio of research volume supported by the reactor to net cost was maintained.

Overview

Neutron beam research under the guidance of Professor Clifford G. Shull, of the Department of Physics, continued to be a major research effort at the MITR-II. Neutron scattering studies in Professor Shull's group emphasized fundamental quantum mechanics.

One experiment measured the group velocity of neutrons in a perfect silicon crystal and found the flight time to be anomalous under Bragg diffraction condition. Another inquiry investigated the validity of the Schroedinger equation. A recent paper by Shimony had suggested the applicability of the neutron interferometer for testing a possible nonlinear variant. Experimentation at the MIT Research Reactor showed no evidence of such a nonlinear term. Present research is directed toward understanding the effect of external perturbation upon neutron propagation through a crystalline medium. This experiment consists of studying the effects of rotating the neutron interferometer. It is hoped to measure neutron phases as a function of various rotational speeds to ascertain the dynamical consequences of inertial forces.

Currently involved in this research are three full-time graduate students, two seeking doctorates and one a master of science. Further theoretical assistance is provided by a visiting professor from Stonehill College. During the past year one Ph.D. has been awarded and two undergraduates worked on their senior theses. Support for Professor Shull's research continued through the National Science Foundation and the US Department of Energy (DOE).

Other activities in neutron beam tube research included the Department of Nuclear Engineering's group of Professor Sow-Hsin Chen and Dr. Charles V. Berney. Significant instrument development was performed on the double-crystal spectrometer to improve control. A master's thesis is largely devoted to a description of this work. Experimental studies included the inelastic neutron-scattering study of crystalline formic acid and neutron-diffraction studies of graphite intercalation compounds. Another master's thesis was completed and several journal publications produced. Future experiments will include further inelastic-scattering studies of molecular crystals and polymers and studies of phase transitions in simple carboxylic acids. The National Science Foundation has supported this research.

The medical research group of Professor Gordon L. Brownell, of Nuclear Engineering, began a new project to develop boron capture therapy for cancer treatment. The scientific objective is the determination of the effectiveness of boron neutron capture therapy for the treatment of brain tumors using an animal model. The overall goal is to obtain adequate information to permit a clinical trial of this therapy modality. Several doctoral students are performing thesis research,

and there is a broad involvement by senior academic and scientific staff from MIT and several other universities and hospitals in the Boston area, as well as national and international collaboration on this important cancer treatment research.

Accomplishments in this year include a beagle tumor model which has been developed for use in this study. Methods of inoculation of tumor have been developed, and techniques for CT scanning to determine location and size of tumor are now available. Studies on neutron distribution in phantoms have commenced. Track etch techniques are being developed to determine the distribution of boron compounds in brain tissues. Support for Professor Brownell's project comes through the National Institutes of Health.

Geochemical analysis studies in Professor Frederick A. Frey's Earth and Planetary Sciences group continued to use the MIT Research Reactor for neutron activation analysis of rocks and minerals. Both radiochemical and instrumental neutron activation are utilized to analyze for a wide variety of trace elements, and neutron activation is a key aspect of a continuing, analytically-oriented geochemical program to determine and interpret the composition of rocks which bear on important geologic problems. Such problems include the evolution and composition of the earth's mantle, which comprises the major mass of the earth beneath the shallow crust, the nature of the volcanic process creating new ocean floor at spreading ridge axes such as the Mid-Atlantic Ridge, and the source and composition of volcanism occurring when oceanic plates collide with continental plates in regions such as the Andes.

These projects typically involve full-time activities of three to five graduate students, Professor Frey, and a visiting scientist. Commonly, another three to five students use the reactor in their geochemical research on a part-time basis; i.e., activation analysis is not their major analytical approach. Support for Professor Frey's research is principally from the National Science Foundation.

Radiochemistry and nuclear trace analysis in the Nuclear Reactor Laboratory continued to grow and provide essential support for a variety of interdisciplinary and interdepartmental projects. The Radiochemistry and Trace Analysis group is under the direction of Dr. Morteza Janghorbani. A brief description of major research involvement follows.

Stable isotopes are being used to study human nutrition. Institute faculty involved in this research are Professors Vernon R. Young, Nevin H. Scrimshaw, and Noel W. Solomons of the Department of Nutrition and Food Science. Six graduate students and postdoctoral trainees have been involved in this research. Research funding is obtained from various sources including the National Science Foundation, the National Institutes of Health, and the US Department of Agriculture.

Trace elements in oceanography are being investigated, partially in collaboration with Professor John M. Edmond and his graduate students. In addition, two research projects with funding from the National Oceanic and Atmospheric Administration are active as NRL projects.

The health effects of coal utilization are being studied in an interdepartmental project. Professors Adel F. Sarofim and Jack B. Howard, Chemical Engineering, obtain essential support for their research project from Dr. Janghorbani's trace analysis group at the NRL. The Electric Power Research Institute has provided the support for this project. Two graduate students are carrying out their thesis research in this area.

Other activities involving service analyses for a variety of problems Institute-wide were carried on.

The Radiochemistry and Trace Analysis group has continued to expand, as the potential uses for these techniques are more clearly recognized throughout the Institute. New senior staff were added and more will be added in the coming year. Several hundred thousand dollars' worth of new capital equipment capabilities have now been developed and the addition of further capabilities is planned.

Nuclear materials research efforts directed by Professor Nicholas J. Grant, of Materials Science and Engineering, and Professor Otto K. Harling, of the Nuclear Reactor Laboratory and Nuclear Engineering, continued at the NRL. In the past year three academic departments, a total of six professors, four visiting scientists, and six thesis research students, participated in the

research project. This project is exploring innovative techniques, such as rapid solidification from the melt, to develop primary structural alloys for the fusion reactor first wall application. The problem of improved irradiation performance for primary structural use is on the critical path for economic fusion reactor development. Progress was made on most fronts of this project. Several alloys were designed and produced and are now undergoing microstructural and mechanical characterization. New facilities, hot cells, and other capabilities were designed and built at the NRL as a part of this project. This alloy development effort, supported by the US DOE is probably the largest single nuclear materials research effort at a US university.

Another nuclear materials project under the direction of Professor Harling involves the use of the MITR-II for a test which is designed to assess the performance of typical fusion reactor materials during operation as part of the fusion reactor first wall. In this unusually sophisticated test, the metal alloy samples are subjected to cyclic temperature changes, cyclic stresses, and alpha bombardment, all simultaneously. Two other professors, three thesis research students, and a visiting scientist are active on this project, which is also supported by the DOE.

Other significant experiments using neutron irradiations included irradiations of TOKAMAK insulator materials for the Plasma Fusion Center, and development and application of track etching techniques for boron and fissionable element trace analysis.

Short-term student projects included: reactor physics and operations studies, friction and wear studies using irradiated materials, neutron activation analysis, determination of U and Pu in bones and teeth, Independent Activities Period Program with track etching, and a UROP Program for identification of boron location in stainless steels. The Reactor Sharing Program, which enables the NRL to provide reactor services to Boston area universities, was renewed with support from the DOE.

Isotope production included weekly production of Phosphorus-32 for a local firm. Medical isotopes including Dysprosium-165, Osmium-191, and Gold-198 were routinely produced for several hospital research centers.

Other services included the testing of security equipment for monitoring of special nuclear materials under a contract with the US State Department Arms Control and Disarmament Agency.

The MIT Research Reactor completed another year of routine operation at 5MW, averaging 83 hours/week for the year. This exceeded the 80 hours/week average of the previous year, when operating time was curtailed somewhat due to failure of the fuel supplier to meet delivery schedules. This has now been rectified through procurement of a two-year supply. Further, computer-aided fuel management studies by the reactor staff have facilitated more efficient use of existing fuel, and the DOE, which funds the fuel, is now supporting a test program to develop an improved fuel element design leading to a longer lifetime. The NRL is participating in this study.

Existing reactor facilities continue to be well utilized although much more use could be accommodated. The principal new facility is a double hot cell installed in the containment building adjacent to the reactor. Remote manipulators permit the examination and testing of materials exposed in the reactor for radiation damage or other purposes. Amendment of the reactor license should shortly be completed, which will permit testing in the hot cells of radioactive materials received from other sources, such as the National Laboratories. Additions and improvements of reactor experiment facilities included a fully operational automated rabbit system for sending and receiving irradiated specimens to radiochemistry laboratories in NW-13, and improved reactor vertical graphite test facilities. The upgrading of reactor instrumentation and radiation protection equipment was continued. A total of 2,350 irradiations were performed in the past fiscal year compared to 1,192 in the previous year.

The operating staff of the reactor was significantly impacted during the past year, primarily as the result of nuclear industry growth (the number of new plants coming on line) but also by the Three Mile Island accident. For both reasons there has been a strong demand by the industry and the Nuclear Regulatory Commission for well-trained and experienced personnel. Several of the reactor staff were lured away during the year, and we are still in the rebuilding process. A direct result of Three Mile Island was an increased awareness of our existence by the news media and a series of internal audits by the MIT administration (in addition to the usual NRC inspections) of reactor safety, security, and nuclear material accountability, the results of which were gratifyingly satisfactory.

Possibilities for broadening the activities of the Nuclear Reactor Laboratory and increasing the utilization of MITR-II were studied and decisions were made to emphasize two new research areas. Applications of the MITR-II in the life sciences and neutron scattering were defined as promising thrust areas for the development of new research programs. The thrust in the life science area coincides and is coordinated with an increased activity in the nuclear medicine area by the Department of Nuclear Engineering and the Whitaker College of Health Sciences, Technology, and Management. The objective of the new activity in neutron scattering is to provide an in-house capability to service the needs of staff from the academic departments and interdepartmental laboratories. In the past there has not been a convenient way for nonspecialists to use the MITR-II for neutron scattering applications which were not major projects in themselves.

The fiscal performance of the Nuclear Reactor Laboratory was good during the past year. It was possible to stay close to the estimated budgeted deficit. The ratio of research volume attributed to NRL operations and the net cost was continued at a favorable ten-to-one ratio. Further improvements in the research utilization of the MITR-II can be achieved by activities such as the development of the new thrust areas described above.

OTTO K. HARLING

Patent, Copyright and Licensing Office

Patent Trends

Increased research funding by the Department of Energy (DOE) over the past few years continues to impact on the patent program, due to DOE's policy of maintaining ownership of inventions made or actually reduced to practice in the course of DOE-funded research. Additionally, DOE has been resistant to the issuance of waivers of title in advance of the award of research funds, as well as to the grant of waivers on identified inventions. This policy has interfered with the Patent Office's ability to file promptly on DOE-funded inventions, and has impeded licensing efforts on such inventions.

This past year, however, two encouraging events have occurred which indicate a positive change. The Senate has passed the University and Small Business Patent Procedures Act (often called the Dole/Bayh Bill) by an overwhelming vote. This bill allows universities and small businesses to retain ownership of inventions made in the course of government-sponsored research and eliminates the necessity of dealing with each agency on an individual basis. It is anticipated that this uniform patent legislation will receive a favorable vote from the House. In the meantime, the Department of Energy has recently granted a pre-award waiver to MIT covering a significant body of technology developed both at Lincoln Laboratory and on campus, and has indicated the likelihood that another pre-award waiver will be granted in the near future. Additionally, MIT has been successful in obtaining an Institutional Patent Agreement with the Department of Commerce, under which the Institute will retain title to inventions made in the performance of research sponsored by the National Oceanic and Atmospheric Administration (NOAA).

Recent United States Supreme Court decisions also should prove to have a positive effect on MIT's patent program. Specifically, the recent decision affirming the patentability of human-made living organisms should encourage disclosures in this area. The manner in which this case will ultimately impact on the patent program, as well as any existing policy implications in this respect, must, of course, be fully reviewed by the Institute if and when disclosures in this area begin to be made.

The Supreme Court also has affirmed the legal right of the owner of a chemical process to link the licensing of the patented process with the sale of the unpatented resulting product or article used in the process. This decision should strengthen the Institute's ability to license process technology.

A major portion of the Office's time has been devoted during the past year in cooperation with the Office of Sponsored Programs (OSP) in the negotiating of significant long-term research programs with industry. The disposition of intellectual property has been and should continue to be a major issue in all such negotiations with industrial firms.

Disclosures and Licensing

During the past fiscal year, 142 disclosures were received, 88 US patent applications were filed, and 47 US patents issued. Additionally, 100 patent applications were filed in foreign countries corresponding to 14 US applications. Gross royalty income from patent and copyright licensing totaled \$1,441,331. In addition, industry committed approximately \$464,000 in the form of research funding which is directly attributable to the licensing program, as this research support is in conjunction with option/license agreements to inventions. Licensing efforts during this past year have concentrated in the following general areas: medical/biological applications including skin-equivalents, noninvasive detection methods, blood pressure reduction/memory aids, and continued microcarrier developments; energy technology including solar cells, laser processes, and gasification processes; improvements in the fabrication of a variety of electronic/computing circuits and assemblies; and rheocasting processes.

In keeping with a program formulated in conjunction with Lincoln Laboratory, considerable effort has been devoted by this Office during the fiscal year on encouraging invention disclosures from Lincoln Laboratory and on attempting to prepare integrated licensing portfolios on specified technologies. Towards this end, legal assistance to the Laboratory has been increased significantly during the fiscal year. The Patent Office also has been successful in obtaining a decision in MIT's favor by the Court of Customs and Patent Appeals on a Lincoln Laboratory invention in the area of thin films which has been licensed to one industrial firm and optioned to another in specified fields-of-use. It is hoped that this Court decision will encourage the licensees to accelerate development of this invention.

Copyrights

In response to the Copyright Act of 1976, this Office participated in reviewing the Institute's recently distributed memorandum covering highlights of the new law such as fair use of copyrighted works, library photocopying, and copyright in computer software. The Institute also has expressed its opposition to passage of the Computer Software Copyright Act of 1980 (H.R. 6934) which, in its present form, may seriously impair MIT's ability to successfully negotiate copyright license agreements.

Personnel

The Patent Office is presently conducting a search to replace a vacancy caused by the retirement during this fiscal year of one of the patent attorneys in the Office.

ARTHUR A. SMITH, JR.

Patent Marketing

During the past year, MIT's patent marketing effort has centered on developing qualified contacts at industrial corporations which might have an interest in licensing inventions resulting from MIT's research activities. These contacts are segregated according to specific technology areas, and receive information on relevant inventions as soon as the patent application is filed. This information program is closely coordinated with the Industrial Liaison Program and is augmented by participation in technology transfer shows. This past year over 200 new contacts were made at TechEx '80 in Atlanta and at TechTransfair '80 in Utrecht, Holland. MIT's invention

portfolio is also disseminated through Control Data Corporation's Technotec data base and the computer search service of Dr. Dvorkovitz and Associates.

Expressions of interest in an invention are followed up by meetings between the potential licensee and the inventor. This often results in a research grant to the inventor to fund further development. This year, more than \$340,000 of research support was generated as a direct result of marketing contacts.

BRUCE D. WEDLOCK

Plasma Fusion Center

During the past year there has been significant technical progress in Plasma Fusion Center (PFC) research programs. Outstanding technical excellence is the primary cornerstone of all PFC research activities, and a major emphasis is placed on providing the intellectual environment that fosters independent creativity, both at the individual researcher level and on the scale of major fusion projects such as Alcator C. An important strength of the Plasma Fusion Center, and more broadly speaking, of MIT as an institution, is the ability to evolve new ideas and concepts in critical physics and technology areas required for development of fusion energy, and to train professional researchers. Therefore, in the years ahead, there will be necessarily a continued increase in emphasis on the involvement of additional faculty, students, research scientists, and engineers in both new and existing PFC program areas.

The Plasma Fusion Center technical programs are supported by the Department of Energy's Office of Fusion Energy. During the past year, the funding level has been approximately \$14 million. There are about 225 personnel associated with PFC research activities. This includes: 25 faculty members (with participating faculty from Aeronautics and Astronautics, Electrical Engineering and Computer Science, Materials Science and Engineering, Mechanical Engineering, Nuclear Engineering, and Physics), more than 80 research scientists and engineers, 70 graduate students, and 50 support personnel. At the present time, the Plasma Fusion Center's major experimental and engineering facilities are located at several sites on the MIT campus, including NW13 (Nuclear Engineering), NW14 (National Magnet Laboratory), Building 36 (Research Laboratory of Electronics), Building 38 (Electrical Engineering and Computer Science), NW16 (PFC headquarters), NW20 (PFC 220 MW Alternator), and NW21 (Nabisco Laboratory).

ALCATOR CONFINEMENT EXPERIMENTS

The Alcator experimental program constitutes one of the most successful and prominent tokamak confinement programs, both nationally and internationally. The primary objective of the PFC Confinement Experiments Division, headed by Professor Ronald Parker, is to develop the basic physics understanding of the stability, transport, and radiation properties of high-temperature plasmas at near-reactor conditions and to develop methods for heating plasmas to fusion temperatures. The main Alcator experimental activity areas include: equilibrium, stability, and operations (Dr. David Overskei); confinement studies (Dr. Awinash Gondhalekar); plasma-wall interactions (Dr. Earl Marmor); and radio frequency heating (Professor Miklos Porkolab and Dr. Jack Schuss). Professor Bruno Coppi and Professor Parker are overall Alcator program principal investigators.

In 1979, we were saddened by the sudden and unexpected death of Professor Lou Scaturro, Assistant Professor of Nuclear Engineering, and a respected teacher and experimentalist in the Alcator Program. Professor Scaturro will be greatly missed by his students and colleagues.

We summarize here the significant progress made during the past year in several of the Alcator experimental program areas.

Alcator A

The Alcator A is a relatively small (minor radius = 10 cm, major radius = 54 cm) tokamak which is able to operate at extremely high toroidal field strengths (up to 100kG). The Alcator A program has continued to provide basic physics information pertinent to high-temperature plasma behavior. Specific programs now in place are aimed at the understanding and control of plasma-wall interactions. Important results have been obtained during the past year on the problems of impurity transport and removal of particles by interaction with the limiter. Studies of silicon impurity transport indicate that there is no accumulation of impurities in the center of the plasma, and that the confinement time increases with toroidal current and the mass of the background plasma ions. Experiments also have been performed to determine the efficiency of particle removal from the limiter shadow by a passive mechanical limiter. Measurements indicate that one to two percent of the particles leaving the plasma may be easily removed by pumping ports in the immediate area of the limiter.

An additional major program on Alcator A is a modestly powered (100 kW) RF heating experiment near the ion cyclotron frequency, which for Alcator A is about 100 MHz. The experiment is providing information on the physics of wave penetration, heating mechanisms, and efficiency, as well as information on the technological problems of vacuum window and RF coupler design. This experiment may be considered prototypical of the much higher power experiments planned for Alcator C, and the results are being integrated into the design of that program.

During the past year, a design study activity has been initiated to examine modifications to the Alcator A tokamak. An important aspect of this device would be the basic study of MHD activity at high densities and high temperatures, with particular emphasis on understanding and controlling major disruptions. In order to pursue this effort, the Alcator A Bitter magnet would be replaced by a Bitter magnet intermediate in size between Alcator A and C, incorporating external helical windings. The helical windings will be capable of adding a rotational transform of 0.2 to the transform generated by the toroidal current. The size, magnetic field, and plasma current will be chosen in order to enable direct comparison with Alcator C and prior Alcator A performance. This modification should allow exploration of stable, low q (~ 1.5) operating regimes. It should also allow much better control than is presently available during startup of tokamak discharges. It is expected that this modification will take two years, beginning with detailed magnet design early in fiscal year 1981, leading to operation at the end of fiscal year 1982.

Alcator C

Alcator C is an upgrade of the A device, in which the plasma minor radius has been increased to 16 cm, the major radius to 64 cm, and the maximum toroidal field strength to 140 kG. This machine is powered by a new power supply, in which the prime power is supplied by a 220 MW alternator. The alternator is 25 years old, having supplied power for this length of time in the Consolidated Edison system. Due to poor economy of the steam turbine drive, the system was retired and the alternator donated to MIT.

As a result of the C design, parameters even closer to those required for fusion are expected to be achieved. During the first phase, in which the only power to the plasma is supplied by the ohmic heating system, values of the density-confinement time ($n\tau_E$) product approaching $10^{14}\text{sec-cm}^{-3}$ and temperatures approaching 2 keV are expected to be achieved. This value of $n\tau_E$ is well above the minimum required for energy breakeven, although actual breakeven requires higher temperatures. Plasma equilibrium, stability, fueling, and purity are the main physics issues investigated during this phase.

During the past year, Alcator C has operated at toroidal fields in the range 60 kG - 100 kG and plasma currents up to 525 kA. These represent about 75 percent of the design capability. The maximum $n\tau_E$ values are now comparable to the best values achieved on Alcator A, and an increase to $n\tau_E \approx 5 \times 10^{13}\text{cm}^{-3}\text{-sec}$ is expected during the summer of 1980. Electron temperatures of 1.5 keV have been achieved, and advanced limiter designs for Alcator C have been developed that withstand average power loads of 1 kW/cm^2 .

RF Heating

Further improvement of plasma parameters in Alcator C will require additional energy input. Phase II of the Alcator C program has as its objective the increase of plasma temperature from 2 keV to 4 keV or more. For this purpose, two radio frequency heating methods are being developed in parallel, and will be investigated intensively on Alcator C during the remainder of 1980 and in 1981.

The first heating method will use 4 MW of power at the lower hybrid frequency, which is about 4.6 GHz in Alcator C. The second heating method will employ up to 4 MW of power at the first or second harmonic of the ion cyclotron frequency. Lower hybrid heating is the primary approach selected for plasma heating on Alcator C. However, the ion cyclotron heating program, which has been initiated on Alcator A, will be explored in parallel with lower hybrid heating and will be emphasized on Alcator C in the event that this method proves more successful. Key physics issues in both RF heating programs include RF wave penetration into the plasma, heating mechanisms and efficiency, and the effect on plasma stability and confinement. Technological issues are concerned with RF power transmission through vacuum interfaces, power densities achievable, and practical RF coupler design.

Alcator D

During 1980 and 1981, RF heating and ohmic heating experiments on Alcator C are expected to reach a level of achievement that will give a clear direction for Alcator D or a major upgrade of Alcator C. Design activities for the next step in the Alcator program have been initiated and will be intensified as the Alcator C results evolve. These activities are exploring two alternative paths. The first design approach is examining the optimum upgrade of Alcator C that can take full advantage of the RF heating capabilities associated with the lower hybrid and ion cyclotron heating equipment. The full 10 to 15 MW of ion cyclotron capability cannot be utilized in Alcator C due to limited access. An upgraded toroidal field coil design with more ports will be examined as a replacement of the present coil. The increased neutron yield for such a device will require location in a shielded installation in the PFC Nabisco facility. The second, more aggressive approach is examining compact high-field designs that lead to an early D-T ignition experiment. This device may be RF heated and utilize limited compression.

APPLIED PLASMA PHYSICS RESEARCH

The primary objective of the PFC Applied Physics Research Division, with Professor Ronald Davidson as acting head, is to develop the basic experimental and theoretical understanding of plasma heating and confinement properties. Present applied physics research activities include: experimental research on the Versator II tokamak (Professors George Bekefi and Porkolab); experimental research on the Constance I and II mirror devices (Professor Louis Smullin); fusion theory and computations (Professors Tom Antonsen, Abraham Bers, Thomas Dupree, Jeffrey Freidberg, James McCune, Kim Molvig, and Professors Coppi and Davidson); development of the MACSYMA symbolic manipulation system (Professor Joel Moses); plasma diagnostics and laser development (Dr. Daniel Cohn and Professor Benjamin Lax); development of advanced fusion concepts (Professor Lawrence Lidsky); and basic experimental and theoretical research on intense charged particle beams (Professors Bekefi and Davidson).

We summarize here the significant progress made during the past year in selected applied plasma physics research areas.

Versator II is a medium-sized research tokamak (major radius = 40.5cm; minor radius = 13cm; toroidal magnetic field = 15kG) with primary emphasis on basic investigations of plasma heating and confinement properties. Versator II operates routinely with plasma density in the range $10^{13}\text{cm}^{-3} - 4 \times 10^{13}\text{cm}^{-3}$, electron temperatures of 400-600 eV, and ion temperatures of approximately 100 eV. Easy access and excellent plasma diagnostics make this device ideal for testing various supplemental plasma heating schemes. At this time, lower hybrid heating experiments are under way in which 150 kW of RF power at 800 MHz is available for injection into

the tokamak. In addition, research is in progress to investigate electron cyclotron resonance heating of the plasma. For this purpose, a gyrotron oscillator, capable of supplying 150 kW of RF power at a frequency of 35 GHz, is being installed on Versator II in collaboration with the Naval Research Laboratory.

Plans are also under way for designing Versator III, an upgraded version of the present device. Larger-scale RF heating experiments are planned for Versator III and possibly a series of heating studies using intense relativistic electron or ion beams. Two high-voltage accelerators are available and capable of supplying 20-100 kA of electrons at energies of 0.5-1.5 MeV.

At the present time, the electron beam accelerators are being used in the study of relativistic electron and ion diodes with emphasis on optimizing the beam quality and current density. The generation of intense coherent radiation is actively pursued using two different approaches. One approach utilizes a relativistic magnetron capable of emitting approximately 1 GW of radiation at centimeter wavelengths. The other approach is a Raman-type free electron laser designed to generate megawatts of coherent radiation at millimeter and submillimeter wavelengths.

Constance I and II are medium-sized mirror research facilities with primary emphasis on the basic experimental development of RF and beam-plasma techniques for stabilization of mirror loss-cone instabilities. During the past year, the Constance II mirror facility (midplane magnetic field = 5 kG), has been improved and modified, and a multi-channel data acquisition system -- connected to the internal MIT CHAOS computer network -- has been put into operation. In addition, an improved plasma gun using a newly developed, fast gas valve, has been tested, and a 100 kW pulsed RF source has been built for ion cyclotron resonance heating experiments in Constance II. During the past year, basic supporting research has ranged from investigations of instabilities in negative ion sources to the calculation of electron trajectories in space-charge-limited magnetron injection guns.

In the plasma theory and computations area, there has been considerable technical progress during the past year in a variety of important areas. Recent studies include: a) the continued development of a self-consistent theoretical model describing anomalous electron energy transport in tokamaks; b) basic investigations of the MHD stability properties of tokamak plasmas, and the determination of stable operating regimes at moderate values of plasma beta (the ratio of plasma pressure to magnetic pressure); c) the development of a self-consistent kinetic description of the free electron laser instability for arbitrarily large values of the transverse wiggler magnetic field; d) continued theoretical investigations of RF heating, including basic studies of the interaction of lower hybrid waves with plasmas, current generation, and plasma heating; e) basic studies of the MHD stability properties of toroidal fusion systems with external helical windings; and f) fundamental nonlinear studies of the influence of stochastic magnetic fields on turbulent transport in high-temperature plasmas.

MACSYMA is a symbolic manipulation program implemented on the MACSYMA consortium PDP-10 at MIT and available to the magnetic fusion community through the National Magnetic Fusion Energy Computer Network. The MACSYMA effort involves the maintenance and development of the MACSYMA system, its underlying MACLISP system, and the ITS operating system, all of which operate on the MACSYMA consortium PDP-10. A new project is under way to develop a LISP system, called NIL, which is exportable and can support MACSYMA on recently available large-address machines such as DEC VAX-11. In addition to the ongoing algorithm development for the symbolic manipulation of algebraic structures, an effort also has been initiated to implement improved I/O facilities such as a two-dimensional display editor for mathematical expressions.

In the area of advanced diagnostic development, a heterodyne receiver using advanced Schottky barrier diode technology has been used to make far-infrared measurements of cyclotron emission from the Alcator A tokamak plasma. Significant increases in sensitivity relative to other techniques have been achieved. A pulsed 700 kW, 385 μm D₂O laser system has been developed for Thomson scattering measurements of ion temperature in conjunction with the heterodyne receiver. The entire Thomson scattering system will be tested on the Alcator C tokamak beginning in late 1980. The development of a far-infrared laser Thomson scattering system will represent a major contribution to the development of plasma diagnostics.

FUSION TECHNOLOGY AND ENGINEERING

The Fusion Technology and Engineering Division, headed by Dr. D. Bruce Montgomery, provides engineering support for the advanced design projects and develops advanced superconducting magnet technology for the national fusion program. Research activities include: advanced design for the proposed Alcator A modification and for the proposed Garching high-field Ignition Test Reactor; responsibility and design support for the magnetics systems of the Engineering Test Facility (John Williams and Roger Derby); responsibility for a National Divertor Development program to develop improved magnetic divertor concepts (Dr. Ted Yang); the development of forced-flow superconductors for application to advanced fusion devices (Dr. Mitchell Hoenig); and basic research on the development of ductile superconducting materials (Dr. Simon Foner, Professor Robert Rose, and Dr. Brian Schwartz). During the past year, there has been significant progress in each of these activities. We summarize here progress in a few selected areas.

The next major step in the US fusion program will be a fusion engineering device presently known as the Engineering Test Facility (ETF). The Plasma Fusion Center has been selected by the Department of Energy to take responsibility for the Magnetics Branch of the ETF Design Center activities. This work is carried out in close cooperation with the ETF Design Center Headquarters at Oak Ridge National Laboratory, which has overall responsibility for systems integration and management of ETF design activities. Dr. Derby, MIT Magnetics Branch Manager at Oak Ridge National Laboratory, is responsible for coordinating the design work done by General Electric, the industrial magnetics contractor, and the support magnetics design work done at MIT and elsewhere in the country. The superconducting magnet systems will be an order-of-magnitude larger than any current projects and hence represent the most demanding magnet design project ever undertaken.

The PFC has been asked by the Department of Energy to formulate a national program in Divertor Technology. A long-burning fusion reactor must deal with the buildup and removal of helium "ash" and impurities, and magnetic or mechanical divertors are considered an extremely demanding but necessary component. During the past year, Dr. Yang, a recognized expert in this area, joined the Plasma Fusion Center to head the divertor development program. Professors Lidsky, Borivoje Mikić, and Neil Todreas of the Department of Nuclear Engineering are involved in various technical aspects of the program, carrying out pilot experiments, preliminary design and planning of the national program.

Critical experimental tests also are being carried out in the development of forced-flow conductors for superconducting fusion magnets. The supercritical helium-cooled conductor, conceived and developed by the magnet group, has been selected by Westinghouse for the 2 x 3 meter niobium-tin coils for the Large Coil Project at the Oak Ridge National Laboratory, and for the 12 tesla High Field Test Facility at the Lawrence Livermore Laboratory. Heat transfer in supercritical helium is being investigated, and a significant discovery has been made concerning the strong effects of sonic reflections within the conductor.

Basic research on advanced superconducting materials is also a major fusion engineering activity in the Plasma Fusion Center and the Department of Materials Science and Engineering. The objective is to develop materials and techniques for producing superconductors capable of generating 15 tesla magnetic fields and sufficiently ductile to be suitable for advanced fusion devices. This research emphasizes finely divided materials, and sufficient progress has now been made to consider two of the techniques ready for commercial scale-up to magnet materials with mechanical properties representing a significant improvement over conventional preparations.

FUSION SYSTEMS

The Fusion Systems Division, headed by Dr. Cohn, carries out a variety of design and reactor physics investigations related to the next generation of fusion devices. Emphasis is placed on the increased understanding of the potential characteristics and technology requirements of power-producing fusion reactors and the development of advanced component technology.

Research activities include: fusion safety and environmental studies (Professor Mujid Kazimi); advanced tokamak systems studies (Dr. Cohn); development of new design concepts for fusion blankets and first wall (Professors John Meyer and Mikić); gyrotron and advanced millimeter source development (Dr. Richard Temkin); millimeter and submillimeter wave detector development (Drs. Harold Fetterman and Peter Tannenwald, Lincoln Laboratory). During the past year, there has been significant progress in each of these activities, and we summarize here progress in a few selected areas.

In the tokamak system studies area, there have been important new computational studies of ignited plasmas. Characteristic spatial features and instability modes have been calculated and new concepts for thermal equilibrium and stability control have been developed. The PFC is serving as coordinator for US participation in the ZEPHYR ignition test reactor (ITR) project at the Max Planck Institut für Plasmaphysik in Garching, Federal Republic of Germany. Related technical activities include the development of improved designs for high-performance copper magnets for the ITR. The tokamak systems study group is also participating in the plasma systems design for the Engineering Test Facility.

In the safety and environmental studies area, a total energy cycle assessment of fusion power production is being developed for the first time. Work is also under way to assess risk from lithium fires in fusion reactors and to compare the safety features of various blanket designs.

A new program aimed at the development of high frequency (~140 GHz) gyrotrons for plasma heating has been initiated. The program involves both experimental and theoretical components. A linear gyrotron theory which facilitates device design has been completed, and a special electron gun is being developed in collaboration with industry.

The basic technology for far-infrared plasma diagnostics is also being developed. Advanced Schottky barrier diode detectors for use in the 300 GHz - 3 THz range will be produced for designated fusion laboratories by Lincoln Laboratory, and these detectors will be used in a variety of applications, including measurements of plasma density by laser interferometry, cyclotron emission studies, and submillimeter laser scattering experiments.

THE NABISCO LABORATORY

Nabisco, Inc., with headquarters in East Hanover, New Jersey, announced on May 31, 1978, that it was donating its property at 184-190 Albany Street, Cambridge, Massachusetts, to MIT. The property was conveyed to MIT on April 7, 1980, following completion of Nabisco's move to a new facility. The value of the 71,000 square foot building and property is in excess of \$1.5 million. The original building was constructed in 1905. Additions and remodeling were done in 1953. The building is constructed of masonry walls, concrete and rock maple floors, steel and wood columns, steel roof joists, gypsum deck roof, and is basically a single-story with a small second floor area in the central section.

The Nabisco Laboratory (NW21) is adjacent to the PFC 220 MW Alternator (NW20) donated by Consolidated Edison Co. of New York, and Plasma Fusion Center research facilities located in the Francis Bitter National Magnet Laboratory (NW14), the Nuclear Engineering Department (NW13), the Nuclear Reactor Laboratory (NW12), and the Plasma Fusion Center Headquarters facility (NW16). The close proximity to these facilities and heavy power make the Nabisco Laboratory an ideal location to house the Plasma Fusion Center's major confinement experiments and engineering test facilities, particularly, the new experimental program planned for tandem mirror research, the upgrades/follow-on experimental devices in the Alcator, Versator, and Constance programs, as well as new experimental activities that may evolve in the torsatron/stellarator area.

The PFC and MIT have made a strong institutional and intellectual commitment to the establishment of a center of excellence for mirror systems fusion research at MIT. In this regard, Drs. Richard Post and Jay Kesner have recently accepted appointments at MIT to initiate a tandem mirror experimental program that will significantly complement the mirror research activities at Lawrence Livermore Laboratory, as well as the ongoing PFC research activities in mirror theory and the Constance I and II experimental program. The Plasma Fusion Center has submitted a proposal

to the Department of Energy for Phase I renovations of the west wing of the Nabisco Laboratory to establish a mirror systems experimental facility that will house the tandem mirror experiment, related support facilities, and follow-on devices in the Constance program. The technical proposal for the tandem mirror experiment is presently in preparation and will be submitted to DOE in fall 1980.

APPOINTMENTS AND PROMOTIONS

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

Appointments include: Dr. Antonsen (MIT), appointed Assistant Professor of Physics in plasma theory; Matthew Besen (MIT), appointed to the technical staff in the Alcator experimental program; Dr. Donald Blackfield (University of Wisconsin), appointed research scientist in the divertor development program, Dr. Boyd Blackwell (University of Wisconsin), appointed research scientist in the Alcator RF heating and fusion technology programs; Michael Carracino (Rotator Services Corporation), appointed to the technical staff in the Alcator experimental program; Steven Fairfax (MIT), appointed to the technical staff in the Alcator experimental program; Dr. Michael Gerver (Cornell University), appointed research scientist in fusion theory and computations; Dr. James Irby (University of Maryland), appointed postdoctoral fellow in the Constance experimental program; Dr. Kesner (University of Wisconsin), appointed research scientist in the tandem mirror confinement program; Mary Knowlton (MIT), appointed to the technical staff in the Alcator experimental program; Dr. Bruce Lipschultz (University of Wisconsin), appointed research scientist in the Alcator experimental program; Dr. Alan Palevsky (MIT), appointed postdoctoral fellow in the intense charged particle beam research program; Dr. Post, appointed senior research scientist in the tandem mirror confinement program; Dr. Robert Potok (MIT), appointed postdoctoral fellow in the tokamak systems study program; Dr. Joel Schultz (Westinghouse), appointed research engineer in the fusion magnet design program; Michael Steeves (Magnetic Corporation of America), appointed research engineer in the superconductor development program; Dr. Reich Watterson (Ecole Polytechnique de Lausanne), appointed research scientist in the Alcator experimental program; and Dr. Yang (Westinghouse), appointed research scientist in the divertor development program.

During the past year, Institute research promotions in the Plasma Fusion Center include: Dr. Cohn, promoted to senior research scientist in fusion systems and reactor physics; Dr. Robert Klinkowstein, promoted to research scientist in the Constance experimental program; and Dr. Stanley Luckhardt, promoted to research scientist in the Versator experimental program.

Internal PFC promotions and appointments to group leader and project leader positions of major programmatic responsibility include: Dr. Cohn, head, Fusion Systems Division; Drs. Fetterman and Tannenwald, co-leaders, Millimeter and Submillimeter Wave Detector Project; Paul Smith, PFC fiscal officer; Dr. Temkin, leader, Gyrotron and Advanced Millimeter Source Development Group; and Dr. Yang, leader Divertor Development Group.

During the past year, there have been several new visiting scientists and engineers in PFC program areas. These include: Dr. Ali Erisen (faculty of Engineering, Izmir, Turkey), neutronics calculations for advanced tokamak systems; Dr. Ian Falconer (University of Sydney), development of ion Thomson scattering diagnostics on Alcator; Dr. Vladimir Fuchs (Hydro-Quebec Research Institute), theory of RF heating and nonlinear wave interactions; Dr. Anthony Hayzen (South African Atomic Energy Board), Alcator experimental program; and Dr. David Sherwell (South African Atomic Energy Board), MHD theory of toroidal fusion systems.

RONALD C. DAVIDSON

Research Laboratory of Electronics

The Research Laboratory of Electronics (RLE), established at the end of World War II, was the Institute's first interdepartmental laboratory. In the years since, it has evolved an on-campus research environment which provides faculty members and their students with the diverse services and facilities of a large laboratory. RLE was originally organized to encourage interactions between teaching and research in the Departments of Electrical Engineering and Physics, but has subsequently had projects involving participants from as many as a dozen academic departments. The research groups, which currently number approximately 30 conduct studies in three broad areas: general physics, plasma dynamics, and communication sciences.

Research in RLE is performed primarily by faculty members, postdoctorals, and students. Approximately 75 members of the faculty are affiliated with the Laboratory, working with about 300 graduate students and 100 undergraduates. The research covers many topics, thus providing opportunities for a wide variety of student theses. During the past year, work done in the Laboratory served as the basis for 16 doctoral, 3 engineer's, 15 master's, and 23 bachelor's theses.

Major support for the research is provided by the Joint Services Electronics Program of the US Army, Navy, and Air Force, as well as other agencies of the Department of Defense, the Department of Energy, the National Science Foundation, the National Institutes of Health, and the National Aeronautics and Space Administration (NASA).

GENERAL PHYSICS

The general physics area contains such subjects as solid state, atomic physics, quantum electronics, and electromagnetics. The Laboratory's research in general physics is primarily concerned with the structure of matter -- of atoms, molecules, and condensed matter. The experimental techniques used in these investigations include radio frequency and optical spectroscopy, X-ray scattering, laser light scattering, photo-acoustic spectroscopy, and nonlinear optics. Some of the research topics in this area are as follows:

Professor John G. King and his associates have continued their studies in molecule microscopy. One form of the molecule microscope, developed by Professor King's group, is being applied to studies of the spatial distribution of non-radioactive, isotopically labeled water throughout various tissues. These experiments are being done in collaboration with Professor Alvin Essig of Boston University's School of Medicine and Professor Alexander Leaf's group at Massachusetts General Hospital. Another form of molecule microscope, developed by Professor King's group, depends on spatial variations in the binding energy of small molecules to biological surfaces. These studies are nearing completion with the testing of various thermal desorption arrays designed to provide localized heating and hence desorption of molecules from the sample surface. The arrays have been fabricated in the Microelectronics Laboratory and the newly established Microstructures Laboratory in the Materials Science Center. Finally, Professor King is undertaking, in collaboration with Professor Anthony P. French of the Physics Department, an improved charge neutrality experiment which should reduce the limit on a possible proton-electron charge difference by as much as four orders of magnitude from its present value of 10^{-21} fundamental units.

During the past year, Dr. John W. Coleman has continued studies of the Auger Electron Microscope (AEM). The AEM is now resolving 1 micron in darkfield images of carbon on tungsten, with an energy window of approximately ± 12 eV around the carbon Auger KLL peak at 289 eV. The main hindrance to better resolution at this time is the lack of facility to align the optical elements and the energy analyzer while an image is being observed. Thru-focus series, however,

can be made by utilizing the inherent energy discrimination characteristic of the mirror/objective lens.

Professor Shaoul Ezekiel and his students have made several important advances in their development of laser inertial rotation sensors for applications in geophysics and relativity. In their precision studies of atom-field interactions, they have shown that atomic recoil plays a significant role in the determination of the spectra.

Professor John D. Joannopoulos' group is continuing studies of the structure and elementary excitations of semiconductor surfaces and interfaces. Attention has focused recently on the development of microscopic theories for understanding the following: 1) monolayer adsorption of metals on semiconductors and Fermi level characteristics, 2) cleavage defects on clean surfaces and their affect on doping, and 3) properties of surface excitons as contrasted to bulk excitons.

Photoluminescence (PL) experiments with steady-state excitation of amorphous SiO_2 , conducted by Professor Marc Kastner and his students, have indicated intrinsic defects similar to those found in narrower band-gap chalcogenide glasses. The temperature dependence of the PL suggests a connection between the barriers to non-radiative recombination and the tunneling modes observed in specific heat and acoustic experiments. The addition of a pulsed molecular flourine laser has made possible the first time-resolved PL experiments on SiO_2 . Because of the higher power excitation, Professor Kastner's group has been able to observe two new PL peaks which had not previously been detected. Each of the peaks has a different time evolution; one of them appears to have two discrete time constants.

Professor Hermann A. Haus and his graduate students have continued their work on the modelocking of semiconductor diode lasers. The highest repetition rate achieved thus far is 5 GHz. A new optical waveguide sampling device was proposed with a 2 psec time resolution. The device is being fabricated in cooperation with Dr. Frederick J. Leonberger of Lincoln Laboratory.

Professor Jin Au Kong and his students have carried out a number of projects in electromagnetic wave propagation and radiation, including: 1) active and passive remote sensing of earth terrain, 2) microstrip antenna studies, and 3) geophysical subsurface probing and communication with dipole antennas. Twelve journal articles and 12 symposia articles have been published in the past year.

Professor David Pritchard and his students have obtained first results from a new apparatus which utilizes recent technical advances in supersonic molecular beams and tunable dye lasers. The apparatus prepares molecules in a specified energy level; then measures the angular dependence of the cross-section for molecular collisions which scatter it to a particular final energy level. In essence, this experiment determines how hard one must hit the molecule (as measured by the scattering angle) to change it to a particular final level. The first studies were of collisions which change the rotational level of the molecule without changing the vibrational level. These cross-sections exhibit a sharp peak at a particular angle -- called the halo angle -- but are essentially zero at smaller angles. The halo angle was found to increase linearly with the increase of the angular momentum; a result consistent with a mechanical model of the atom-molecule interaction in which the collisional impulse is delivered at a limited distance from the center of mass of the molecule. These experiments were conducted in Professor Pritchard's laboratory in collaboration with Professor James Kinsey of the Chemistry Department.

A team including Professors David Staelin, James Melcher, and graduate student Jeffrey Lang has successfully controlled a 1-m square thin wire mesh electrostatically so as to achieve $\sim 10 \mu\text{m}$ rms surface tolerance, even though the mesh was electrostatically biased to twice the level needed to induce the first Rayleigh-Taylor modal instability. In a separate experiment, three such unstable modes were controlled successfully, suggesting that large thin-mesh reflector antennas could be constructed and controlled electrostatically so as to achieve diffraction-limited antenna beamwidths of 10 arc sec or less. This work is particularly relevant for future large microwave reflector antennas in space.

Professor Staelin also has collaborated with Lincoln Laboratory staff member, Robert Harvey, in writing a report which analyzes architectural issues in future large switched communications

networks incorporating satellites. They show that by the year 1995 multiple-switched satellites in a single orbital slot could carry much of the United States domestic long-distance telecommunications traffic at costs that are a fraction of those today.

During the past year, Professor Bernard F. Burke, Research Assistant Perry E. Greenfield, and Visiting Scientist David H. Roberts have intensively studied the double quasar 0957+561, which appears to be the first stellar object to exhibit the gravitational lens effect on an extragalactic scale. The group is using the Very Large Array (VLA) of the National Radio Astronomy Observatory to carry out their experiments. Optical observers have shown that there is a large foreground galaxy close by the southernmost quasar image; by combining radio and optical data it is possible to place stringent limits on the nature of the gravitational lens effect due to this galaxy. These studies imply that the observed radio and light rays come from a single distant quasar which is split into two images by the gravitational field of the foreground galaxy. The radio images are sufficiently complex, however, to rule out the galaxy as the sole contributor to the observed effects unless it had a highly unusual mass distribution. For a number of years, it has been suspected that there is a large amount of "hidden mass" -- perhaps 100 times as much as in the galaxies themselves. The double quasar observations provide the first direct evidence for the existence of such matter. The quasars are changing in brightness with time, and there should be a time delay of months-to-years in their relative intensities. This large-scale cosmological test is now under way using "snapshot" observations taken with the VLA every month.

Professors Alan H. Barrett, Philip C. Myers, and students have continued their radio astronomical studies of the interstellar medium. Among their recent findings are: 1) detection of unusually narrow spectral lines of NH_3 in small dark clouds with reflection nebulae, 2) discovery of ^{13}CO lines in many dark clouds, whose asymmetric line shapes appear to indicate cloud contractions, and 3) discovery of four new sources of radiation from the remarkable long-chain molecule HC_3N . These sources have about the same mass as the Sun and linewidths much smaller than that for free-fall. Professors Barrett, Myers, and students also have continued their work using microwave radiometry to detect thermal radiation associated with breast cancer. Their new microprocessor-based radiometer at 6 GHz in Faulkner Hospital, Boston has a breast cancer detection rate of 85 percent.

Professor Clifton G. Fonstad and his group have recently fabricated segmented-contact, gallium aluminum arsenide double heterostructure laser diodes which exhibit unique features and modes of operation. These devices, built as a preliminary step in the development of integrated mode-locked laser diodes, are significant both because of the mechanism they provide for monitoring and measuring stimulated gain, absorption, and carrier concentration as a function of position along a laser stripe, and because of their usefulness as repeater elements in fiber communication systems. Extensive work also has been done on developing growth capabilities and device fabrication techniques for the semiconductor indium gallium arsenide phosphide. This material will find application in high-speed multiplexers and demultipliers for picosecond optical pulse trains, and in high speed III-V heterojunction microelectronics.

Professor Ralph H. Staley and his group are developing photo-acoustic spectroscopy (PAS) techniques to characterize molecular species adsorbed on surfaces. Their ultimate aim is to investigate modifications of the chemical, physical, and electrical properties of surfaces which may be brought about by the covalent attachment of organic and organometallic molecules. Such information is of particular importance in adhesion and corrosion research. PAS capabilities have been extended to include the mid-infrared spectral range by developing instrumentation which utilizes photo-acoustic detection with a Fourier transform infrared (FTIR) spectrometer. FTIR-PAS is being applied to investigate molecules bound to clean silver surfaces. These systems show a greatly enhanced Raman effect; infrared spectra may help clarify the mechanism of this phenomenon. During the past year, Professor Staley's group also has demonstrated techniques for the attachment, and blocking attachment, of molecules to surfaces using silane reagents.

Professor Frederic Morgenthaler and his colleagues have continued their work on microwave magnetostatic waves propagating in single crystal ferrite thin films. When biased with nonuniform DC magnetic fields, such films allow the synthesis of modes with prespecified characteristics, such as frequency, RF energy distribution, and velocity of energy circulation. Professor Morgenthaler also predicts that the onset of nonlinear effects due to parametrically-induced

spin waves should be governed by instability thresholds that are gradient-controllable. His group has reported the observation of new types of magnetostatic surface waves in rectangular films of yttrium iron garnet (YIG) placed between strips of permalloy and in the plane of the strips.

During the past year, Professor Michael M. Salour and his colleagues have developed a new method of pulsewidth stabilization of a synchronously mode locked dye laser. Their work represents the first attempt to electronically counterbalance noise and other undesirable effects which produce fluctuations, both in the amplitude and pulsewidth of the picosecond pulses. His group also has made the first observation of unidirectional gain induced by velocity-dependent frequency shifts in sodium vapor. This work has led to a novel kind of light-induced switch, wherein the switching is caused by the rapid relaxation of the population inversion under high forward-gain conditions, accompanied by a burst of light.

Professor Erich P. Ippen joined RLE in February, having previously been a member of the research staff at Bell Laboratories, Holmdel, New Jersey. He and his students are continuing the work begun on a sabbatical at MIT two years ago, in the area of picosecond optical phenomena and high speed opto-electronic devices. Experimental programs have been proposed to extend current picosecond technology to infrared wavelengths and to study nonlinear dynamic processes in semiconductor materials and devices.

Professor David Litster and his group are studying the reorientation of dye molecules dissolved in gels of concentration 2 percent to 10 percent gelatine. The measurements determine the local viscosity and interstitial pore size in the gel and the effect of critical fluctuations on molecular reorientation in binary critical mixtures. These studies are being conducted with picosecond pulses from a passively mode-locked dye laser. Litster's group also has used the Kerr effect to measure orientational dynamics of nitrobenzene near the consolute critical point with n-hexane.

During the past year, Dr. Roshan Aggarwal of the National Magnet Laboratory has joined Professor Peter Wolff and graduate students to continue their studies of resonant, impurity-induced, four-photon mixing in n-Ge. This technique has been used to study the magnetic field dependence of the valley-orbit splitting in Ge:P and Ge:As.

The Submicrometer Structures Laboratory, under the direction of Professor Henry I. Smith and Principal Research Scientist John Melngailis, is now fully operational. Submicrometer structures fabricated in the laboratory are being used in a variety of research projects including: one dimensional electrical conduction in sub-1000 Å silicon ridges, electrical properties of submicrometer gratings in Si/SiO₂, x-ray diffractive elements, molecular microscope, electrical signals in cells, graphoepitaxy of silicon and GaAs, liquid crystal alignment, and attachment of organic molecules to submicrometer sites. The facilities and expertise of the laboratory have contributed in essential ways to numerous theses and student projects. At present about two dozen researchers make regular use of the laboratory, including research scientists and professors, visiting researchers, graduate students, and undergraduates. In addition, certain outside collaborations have been established. For example, lattices of silver dots produced in our laboratory have been used at Bell Telephone Laboratories to observe for the first time enhanced surface Raman spectroscopy from lithographically produced silver microstructures.

PLASMA DYNAMICS

The plasma dynamics program seeks to understand the basic properties of ionized media, in regimes that are of interest to controlled fusion, space physics, and astrophysics. Research in this area includes studies of plasma turbulence, heating, confinement, and stability.

The plasma dynamics research program in RLE is operated in conjunction with MIT's Plasma Fusion Center. Staff members hold joint appointments and Department of Energy support for this work is provided by contracts set up under the Fusion Center.

Professor Bruno Coppi and his colleagues have focused their activities on the experimental effort of the Alcator A and C devices. Their purpose has been to realize plasmas that can sustain very high current densities without becoming macroscopically unstable, in order to achieve the highest possible rate of resistive heating of the plasma at relatively high density.

The analysis of a variety of experiments (including Alcator A and C, the Frascati Torus and the Princeton Large Torus) has enabled Professor Coppi's group to formulate analytically a transport model which consistently reproduces the electron-density profile, the electron-energy confinement time, and the particle-density profiles that have been observed experimentally over a wide range of conditions.

Another achievement of Professor Coppi's group during the past year is the identification and analysis of new regions of stability, in the relevant parameter space, for magnetically confined toroidal plasmas with plasma pressure comparable to the magnetic-field pressure. Such plasmas are of great importance for the possible realization of net power-producing fusion reactors.

Professor George Bekefi and Miklos Porkolab are continuing their work on Versator II, a research-sized tokamak designed primarily as a test bed for various plasma heating schemes. They are beginning lower-hybrid heating experiments in which 150 kW of RF power at 800 MHz is available for injection into the tokamak. In addition, work is in progress on electron-cyclotron heating of the plasma. To this end, the group is now installing a gyrotron oscillator capable of supplying 150 kW of RF power at a frequency of 35 GHz. This work is a collaboration with the Naval Research Laboratory.

Plans are under way for building Versator III, an upgraded version of the present machine. In this new tokamak, Professor Bekefi's group plans to continue larger scale RF heating experiments. They are also contemplating a series of heating studies using relativistic electron or ion beams. They have available, at present, two high-voltage accelerators capable of supplying 20-100 kA of electrons at energies of 0.5-1.5 MeV.

The electron beam accelerators also are being used in the study of relativistic electron and ion diodes with a view to optimizing the quality and current density of the ensuing beams. The generation of intense coherent radiation is being studied in two different geometries. One is a relativistic magnetron capable of emitting approximately 1 GW of radiation at centimeter wavelengths; the other a Raman type, free electron laser designed to generate megawatts of coherent radiation at millimeter and submillimeter wavelengths.

Professor Abraham Bers (on sabbatical leave, September 1979 to June 1980) and his research group are investigating various techniques for heating plasmas to generate energy by nuclear fusion. Together with visiting scientist Dr. Vladimir Fuchs and graduate student Leon Harten, he is studying the thermal instability of a plasma heated to ignition by nuclear fusion energy. Mr. Harten has proposed a new technique for heating a plasma so that it will be stable near its ignition temperature. Dr. Robert Berman has suggested a novel means of identifying and calculating the onset of stochasticity in nonlinear dynamical systems. This technique can be used to evaluate the nonlinear interactions between electromagnetic waves and charged particles in plasma heating. Drs. Vladimir Krapchev and Abhay Ram have extended their studies of nonlinear waves in plasmas to explore methods for driving a steady-state plasma current -- a problem of importance to the realization of a continuously operating toroidal plasma reactor.

Professor Louis D. Smullin, Dr. Robert J. Klinkowstein, and graduate students have been studying instabilities in mirror-confined plasmas. Dr. Peter Kenyon completed his study of instabilities in negative ion sources, and graduate student Joseph P. Rymer completed his Master of Science thesis on the study of the Ti-washer plasma gun. A computer program for calculating the electron trajectories in space-charge-limited magnetron injection guns has been developed by graduate student Amin Ezzedine. The Constance II mirror facility has been improved and modified. A multi-channel data acquisition system, connected to the CHAOS computer network has been put into operation; a 100 kw pulsed source has been built for ion-cyclotron-resonance-heating; and improved plasma guns using a newly developed, fast gas valve are being tested.

Professor Thomas H. Dupree and his colleagues are developing a renormalized, analytic theory of the two-point correlation function for a Vlasov plasma. This theory describes a number of novel and complex effects, including fluctuation self-energy and self-trapping effects. The group is

particularly interested in fluctuations moving at particle velocities since these are important for transport mechanisms. Such fluctuations are related to phase space density holes. Professor Dupree's group also has developed a companion theory, based on thermodynamic and entropy arguments, to describe the fluctuations. As a parallel project, they are pursuing an extensive program of computer simulation to test the analytic theory and serve as a guide in its development. They have developed a number of new diagnostics for plasma simulations, including a probability function for fluctuations of given size and magnitude. The ultimate aim of this research is to develop practical methods for predicting the properties of turbulent plasmas.

COMMUNICATION SCIENCES AND ENGINEERING

Research in communication sciences and engineering deals with fundamental studies of signals and systems, and such applications 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. Most 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.

Professors Robert S. Kennedy, Jeffrey H. Shapiro, Dr. Horace P. Yuen, and students, are continuing their work on the propagation and detection of quantum fields. The main objectives of their work are to: 1) formulate propagation models for important optical channels from the underlying physical processes, 2) determine the fundamental limits on detection and communication performance that can be realized with these channels, 3) develop techniques for optical detection and communication which achieve or approach these limits, and 4) establish, by means of experiment, the validity of the theoretical results and guide their future development.

Professors Alan V. Oppenheim, James H. McClellan, Arthur B. Baggeroer, and graduate students have developed a number of new signal processing techniques, and applied them to speech processing, seismic data processing, and image processing. The speech processing work is directed towards low-cost speech compression and enhancement of degraded speech. The seismic data processing studies have led to new techniques potentially useful for exploration seismology. In the image processing studies, new techniques have been developed for restoration of degraded images and image data compression.

Professor Kenneth N. Stevens and his group have continued their research on the development of theories and models for the production and perception of speech. They have emphasized applications of this research to the study and remediation of communicative disorders, and to man-machine communication through speech. An improved system for machine generation of speech from a phonetic description of speech events has been developed; the rules for achieving proper timing, intonation, and speech quality in this synthesis system are based on recent research results in these areas. A doctoral thesis project has studied the constraints on the capabilities of the human vocal tract for generating certain speech sounds at different stages in the growth of the speech-producing structures -- from birth to adulthood -- for men and women. Other projects include experimental investigations of biomechanical control of the speech structures, and studies of the origins of certain errors that are common in the speech of deaf children.

Professor Jonathan Allen and his coworkers have formulated a new computational model for human speech perception based on a focused search over many constraint domains, including phonetic correlates, phonology, morphology, and syntax. To facilitate this research, a phonetician's work station has been constructed for the interactive exploration of large speech data bases.

Professors William F. Schreiber, Donald E. Troxel, and their students are continuing research on computer-assisted image processing systems for graphic arts applications. Full-page composition functions have been incorporated into one system, a second is in pilot production at a large printing company, and a third has just been installed at a large yearbook publisher. These sophisticated systems enable non-technical operators to perform a wide variety of "photographic" operations by computer, resulting in substantial savings in time and materials, while at the same time enhancing quality.

Research by Professor Louis D. Braida and his colleagues (Research Scientist Nathaniel Durlach, Sponsored Research Staff Adrian Houtsma and William M. Rabinowitz, and Research Associate Charlotte M. Reed) is concerned with auditory perception and speech communication aids for the hearing impaired, the deaf, and the deaf-blind. Work on auditory perception is focused on intensity-perception, pitch perception, and binaural interaction. This work involves extensive psychophysical experimentation on both normal and impaired listeners, and the construction of quantitative models of the auditory system. Work on aids is focused on the development of improved signal-processing schemes for hearing aids and on the tactile communication of speech. The work on aids includes study of selective amplification, amplitude compression, and frequency lowering. Also, an attempt is being made to determine the acoustic characteristics of speech that is spoken with exceptional clarity and the extent to which these characteristics can be achieved with signal processing of "ordinary speech."

Professors William T. Peake and Thomas F. Weiss, and Drs. Nelson Y.S. Kiang, John J. Guinan, Jr., and Terrance R. Bourk are continuing studies of the auditory system with the Eaton-Peabody Laboratory at the Massachusetts Eye and Ear Infirmary. An anatomical study, carried out by Dr. Guinan in cooperation with associates at the Boys Town Institute, has demonstrated that the neural pathways from the brain to the ear are organized in two distinct groups which start from different brain-stem locations, and terminate differently in the inner ear. The demonstration of this organization should help to determine possible roles of this feedback system in hearing.

During the past year, Professor William M. Siebert extended earlier work on mathematical models of the hydrodynamics of the inner ear or cochlea. The new approach provides accurate numerical results using only modest computational facilities, but even more significantly its simple structure provides explanations of many puzzling aspects of cochlear behavior. In addition, the new model makes it clear that most existing cochlear models are not robust -- small deviations from the usual idealizations can be expected to yield large changes in certain aspects of model performance. Further development of this model has been funded by the National Science Foundation.

The research conducted by the RLE Linguistics group has covered a broad spectrum of subjects, ranging from technical details in the phonology of particular languages to the most basic issues underlying linguistic theory. One noticeable recent development in the field has been the increase of interest in the role that the lexicon -- the list of all the words of a language -- plays in the productions and understanding of utterances. Professor Kenneth Hale and his colleague, Dr. Mary Laughren of the Department of Education, Government of the Northern Territory of Australia, continued research on a lexicography of Aboriginal Australian languages. Professor Joan Bresnan has been working intensively on the theory of lexical rules and representations, and has published several papers in this area dealing with passivization, instrumentalization, control, and complementation in English. Professor Noam Chomsky has extended his work in the theory of government and binding as well as his work dealing with problems in cognitive psychology and the theory of knowledge. A major thrust of his research has been in exploring the notion of Universal Grammar as a set of interacting subsystems. During the past year several articles on these subjects have appeared, as well as his latest book, *Rules and Representations*, Columbia University Press, New York, 1980. Professor Morris Halle has worked extensively on the theory of metrical structure. He is presently preparing a monograph on metrical phonology, coauthored with Dr. Jean-Roger Vergnaud of the University of Massachusetts at Amherst.

PETER A. WOLFF

Vice President, Resource Development

The past year, which saw the successful conclusion of the MIT Leadership Campaign, brought both great satisfaction and serious concern to all those involved in this tremendous effort to secure the financial stability of the Institute. The Campaign, begun in April 1975, with the goal of providing MIT a total of \$225 million in private support over five years, concluded in April 1980, with commitments totaling \$250.2 million.

Major achievements of the Campaign include: commitments of \$40.1 million to establish new endowed professorships and \$13.6 million to student financial aid; the acquisition of construction funds for a new Athletics and Special Events Complex; the establishment of the Whitaker College of Health Sciences, Technology, and Management, as well as the acquisition of construction funds for buildings to house the College and the MIT Medical Department in a new complex on the east campus; and the strong effort by MIT alumni which made possible the renovation of Huntington Hall (Room 10-250) and the installation of the new Alumni Center and the Margaret Hutchinson Compton Gallery in Building 10. Of special significance was the Campaign's role in raising the annual level of cash flow to the Institute, from an average of \$22 million in the three years immediately preceding the Campaign to an average of \$36 million in the past three years.

Although the Campaign total was most gratifying and encouraging and went far beyond the original total goal, it masks three serious problems:

- 1) A number of specific goals within the Campaign plan -- goals which are vital to the future strength of the Institute -- were not fully met. In the "Endowment" category, five more professorships are sought to meet the original goal for new chairs, and still others are sought to meet needs which have developed recently. Additional funds for research and innovation are also urgently needed. Under "Facilities," particularly severe shortages exist in funds for student housing, and for School and department renovations. Funds for "New Program Support" and unrestricted use continue to be of utmost importance in assuring MIT's ability to pursue important areas of teaching and research.
- 2) The Campaign took place during a period of unprecedented national inflation, which not only severely curtailed the real purchasing power of both new and existing Institute resources, but also made funds more difficult to raise. By 1980, \$1 was worth about 40 percent less than in 1975.
- 3) Because the Institute environment is dynamic rather than static, new areas of teaching and research continued to emerge during the course of the Campaign, and these require new resources -- both capital and program -- if we are to move forward. Funds are needed for new priorities and major initiatives throughout the Institute. Among the major new developments requiring funds are the Program in Science, Technology, and Society; the Centers for the Brain and Cognitive Sciences; the expanding program in very large scale integrated circuits; a new computer teaching facility for the Department of Electrical Engineering and Computer Science; the renovation program for the Sloan School of Management; and a new Center for the Arts and Media Technology. Many other needs exist in each of the five Schools, the Whitaker College, and various interdisciplinary laboratories, programs, and centers.

Thus, even though the Leadership Campaign exceeded its total dollar goal, the Institute must continue to seek substantial new resources to maintain and expand teaching and research efforts. This difficult fiscal situation is far from uncommon among major private universities who have recently completed successful capital campaigns. Its resolution requires that MIT maintain a vigorous and cost-effective development program as we enter the post-Campaign period. If the Institute is to have sufficient funding for ongoing and new priorities, the annual level of cash flow must be kept at or above the higher levels achieved during the Campaign. Without a substantial and carefully focused development effort, this cannot be achieved.

Vice President, Resource Development

To help meet this challenge, Resource Development began a substantial reorganization during the closing months of the Leadership Campaign. The essential mission of the organization remains unchanged: to ensure sustained and increasing support for MIT's new and ongoing programs, from individuals, foundations, and corporations. The basic goals will be to maintain and increase the support of those now giving to MIT, and to bring in new donors who share an interest in, and commitment to, the educational and research objectives of the Institute. A well-organized and motivated organization, as well as increased involvement by the academic deans and other faculty members in development activities, are essential for the achievement of these tasks.

The basic reorganization was largely completed with the end of fiscal year 1980. With the close of the Campaign, Resource Planning was phased out as an organizational entity and Nelson C. Lees assumed broadened responsibilities as Director of Resource Development. The Development Office, under the leadership of Dr. Vincent C. DeBaun, will continue as the central data bank and clearinghouse for development activities.

In the individuals area, the Volunteer Leadership Appeal (VLA) was terminated and its successor organization, Leadership Gifts, was initiated to continue the important process of identification and cultivation of prospective donors of major gifts. The area is headed by Donald P. Severance, who led the successful VLA effort during the Campaign (and who earlier served as Executive Vice President of the Alumni Association). The MIT Sustaining Fellows, chaired by Breene M. Kerr, Class of 1951, with staff support directed by Executive Officer Eric C. Johnson, will continue its efforts to involve and recognize MIT benefactors.

Close relationships with industry will continue through MIT's Office of Industrial Liaison, through a restructured National Business Committee (NBC) and through increasing contacts with corporate foundations. Industrial Liaison, directed by Professor James D. Bruce and comprising the Industrial Liaison Program and Associates Program (the latter directed by Cynthia C. Bloomquist), will be further emphasized as a principal source of unrestricted corporate support. The NBC, formed during the Campaign, has been restructured with the basic mission of increasing the Institute's contacts with industry throughout North America. The NBC is chaired by Richard L. Terrell, Class of 1958, with staff support led by Robert Hagopian, Director of Corporate Relations. Dr. DeBaun has taken on special responsibilities for a program of foundation and corporate foundation contacts.

In the past several years the Office of Planned Giving and Legal Affairs, under the direction of D. Hugh Darden, has broadened its activities and has expanded its relationships with both Resource Development's Leadership Gifts area and the MIT Alumni Association. These efforts are expected to continue and intensify.

During the past year it has become increasingly evident that development communications, both within and outside MIT must be improved. The offices of Proposals and Publications and Donor Relations have been merged into a new effort, the Office of Communications, directed by Deborah J. Cohen. This group will have special responsibility for carrying out an augmented program of donor relations and cultivation, working closely with MIT faculty and staff.

The need for a special memorial gifts program has been identified. This program is being developed by Clare K. Chapman, Special Assistant in Resource Development, in close cooperation with the Office of Planned Giving and Legal Affairs and the Alumni Association.

During the past several years since his retirement as Dean of the Graduate School, Irwin W. Sizer has effectively helped to launch the NBC and has ably assisted in identifying and encouraging the involvement of many major donors to the Institute. We are delighted that Dean Sizer will continue in his position as Consultant in Resource Development, with broadened responsibilities.

MIT Leadership Campaign

Exactly five years after its inauguration, the MIT Leadership Campaign concluded on April 22, 1980, with a total of \$250,231,897, from more than 33,000 donors, committed against the original goal of \$225,000,000. The Campaign was the largest fund-raising effort in MIT's history, and the third largest capital campaign among US universities at the time of its announcement. The conclusion was marked by several banquets across the nation, with MIT's senior officers and

prominent Campaign volunteers in attendance. By the closing date, almost three-quarters of the total commitments had already been received. The two tables below summarize the strong financial results.

MIT LEADERSHIP CAMPAIGN
FINAL SUMMARY, AS OF APRIL 22, 1980

SOURCES

INDIVIDUALS

Living Alumni	\$ 49,954,973	
Living Friends	23,038,335	
Total Living	<u>\$ 72,993,308</u>	
Deceased Alumni	\$ 15,336,271	
Deceased Friends	4,786,658	
Total Deceased	<u>\$ 20,122,929</u>	
Total Individuals		\$ 93,116,237

FOUNDATIONS

(including individuals giving through foundations) 80,768,818

CORPORATIONS

Corporate Gifts and Grants	59,442,191	
Industrial Liaison	<u>15,295,149</u>	
Total Corporations		\$ 74,737,340

OTHER

1,609,502

Grand Total \$250,231,897

MIT LEADERSHIP CAMPAIGN
FINAL SUMMARY, AS OF APRIL 22, 1980

PURPOSES

<u>ENDOWMENT</u>	(\$ in thousands)
Professorships	\$ 40,113
Student Aid	13,599
Research & Innovation	11,014
General	<u>3,405</u>
Total Endowment	\$ 68,131
 <u>FACILITIES</u>	
Athletics	6,749
Arts & Media Technology	4,469
Student Housing	2,000
Whitaker College	21,075
Huntington Hall	1,610
Program in Science, Technology, & Society	930
Brain Sciences	3,725
Teaching Computer	914
Other	2,914
Completion of Prior Commitments	<u>16,292</u>
Total Facilities	\$ 60,678
 <u>FUNDS FOR NEW PROGRAMS AND CURRENT USE</u>	
<u>PROGRAM</u>	
School of Engineering	\$ 2,050
Sloan School	925
Brain Sciences	100
Health Sciences & Technology	2,313
Libraries	100
Arts	800
Energy Laboratory	6,013
Division for Study & Research in Education	206
Program in Science, Technology, & Society	3,020
Schools, Departments, and Laboratories	<u>70,589</u>
Total Program	\$ 86,116
 <u>UNRESTRICTED</u>	
(available for allocation by MIT when received)	17,313
 <u>INDUSTRIAL LIAISON</u>	
(corporate support of the MIT Industrial Liaison and Associates programs)	15,295
 <u>OTHER</u>	
	2,699
 Grand Total	 <u>\$250,232</u>

The core effort to establish additional professorships resulted in 34 new endowed chairs for senior faculty members and 11 new career development chairs. Important funding was received for several new program areas, including the Program in Science, Technology, and Society, and the Whitaker College of Health Sciences, Technology, and Management, which was established in 1977. Also of special significance was the strong role played by corporations -- accounting for about one-third of total commitments -- which reaffirmed the powerful, and often determinative, relationship that has existed between MIT and industry since the Institute's founding.

Private Support

Total private support of MIT during the past year was \$36.5 million, comprising \$32.3 million in gifts, grants, and bequests and \$4.2 million in support through membership in corporate liaison programs (discussed elsewhere in this report). The total compares with \$37.4 million in 1979, \$34.4 million in 1978, \$29.4 million in 1977, and \$23.9 million in 1976. The impact of the MIT Leadership Campaign is clearly evident.

Sources of gifts for fiscal year 1980 were: alumni, \$10.9 million; nonalumni friends, \$1.9 million; corporations, corporate foundations, and trade associations, \$8.2 million; foundations and charitable trusts, \$10 million; others, \$1.2 million. Included in the totals for alumni and friends are gifts of \$.64 million made to the William Barton Rogers Pooled Income Fund. The total income of \$4.2 million for corporate liaison programs represented a 23 percent increase over the total for fiscal year 1979.

Donors designated expendable and endowed funds as follows: unrestricted, \$5.4 million; departments, \$8.9 million; faculty salaries, \$4.7 million; graduate scholarships and fellowships, \$1 million; undergraduate grants, awards, and loan funds, \$1.5 million; building construction funds, \$5.2 million; other funds, \$4.9 million.

Corporation Development Committee

The members of the Corporation Development Committee, acting individually and corporately, were instrumental in helping to bring the Leadership Campaign to its successful conclusion. During this final year, the 171 members of the committee, including 33 who are also members of the Corporation, assisted in identification of prospects, visits, solicitations, and planning strategies, as well as other volunteer efforts in support of the Campaign.

The annual meeting was held on October 11 with approximately 63 members in attendance and included, as guests, members of the Campaign's Volunteer Leadership Appeal (VLA). The morning session began with remarks on the status of the Campaign and the future needs of the Institute by Chairman Howard W. Johnson, President Jerome B. Wiesner, and President-Designate Paul E. Gray. A panel presentation by representatives from the VLA concluded the morning session. Luncheon at the Stratton Student Center was highlighted by the announcement of the formation of the Sustaining Fellows Program and the presentation of the Marshall B. Dalton Award for exceptional service to MIT to Paul V. Keyser, Class of 1929. "National Energy Priorities and MIT" was the subject of the afternoon program, with a panel discussion by faculty members. The Committee is grateful to the residents of McCormick Hall for generously allowing the use of their public spaces for the annual meeting.

Volunteer Leadership Appeal

The 400 members of the Volunteer Leadership Appeal were supported in their solicitation efforts by Donald P. Severance and a staff of five District Officers. During this fifth and most intensive year of the Campaign, a much larger percentage of the thousands of personal visits to prospective individual donors was made by or with District Officers.

Although the District Officers and volunteers concentrated on soliciting individual Leadership prospects and assisting senior officers, they also became increasingly involved in promoting membership in the new Sustaining Fellows program and aiding in the efforts of the National

Business Committee. They continued to work very closely with those classes involved in special reunion gift programs and with the Office of Planned Giving and Legal Affairs.

At the conclusion of MIT's previous capital campaigns, the ongoing solicitation of major gifts was assumed by senior officers and assisted by a small group of Development Office personnel. This was comparable to the pre-Campaign situations when virtually all solicitation by volunteers was the responsibility of the MIT Alumni Fund. Following this Campaign, however, it is hoped the Institute's annual cash flow will exceed the pre-Campaign level by 75 percent. Obviously, it will be impossible for MIT's senior officers and Resource Development staff to make the thousands of visits to meet such a goal.

Consequently, Resource Development will continue to seek the counsel and help of hundreds of key alumni in our efforts to visit personally about 1,500 major gift prospects. This program, known as Leadership Gifts, will continue under the direction of Mr. Severance with the support of a reduced staff of District Directors (formerly District Officers). Efforts will be focused on continuing conversations with prospective donors who were unable to make their gifts or pledges within the time frame of the Campaign, and on identifying and initiating contacts with hundreds of others. The staff will continue to seek the assistance of many of those volunteers who were so indispensable during the past five years, and will endeavor to augment their ranks with additional volunteers who have a greater knowledge of and keener interest in MIT as a result of the Campaign.

This portion of the report would be incomplete without a tribute to those hundreds of donors and volunteers who made the success of the Campaign possible, and we express our gratitude not only for their work but for those personal friendships that have meant so much to all members of the staff.

National Business Committee

The National Business Committee, chaired very effectively by Richard L. Terrell, Class of 1958, and with a membership of 48 (listed in a previous report), continued to be active in support of corporate solicitations. Supplementing the efforts of the formal Committee, 46 additional alumni have accepted requests to assist, thus substantially increasing the organization's productivity.

Executive responsibility for all functions was carried out by Robert Hagopian, Director of Corporate Relations. Irwin W. Sizer, Dean Emeritus of the MIT Graduate School and Consultant for Resource Development, continued to provide major leadership and support. James T. King, Manager of Corporate Support Programs, Robert H. Bliss, District Officer, and Alice W. Tripp, Administrative Assistant for Special Projects, provided valuable assistance. J. Francis Reintjes, Professor Emeritus in the Department of Electrical Engineering and Computer Science, provided valuable part-time assistance. Senior officers and numerous faculty members gave generously of their time in corporate visits, both in the field and at MIT.

The Committee worked with a broad spectrum of solicitation prospects, based primarily on the 1,000 largest public companies and 100 largest private companies. Committee members and other alumni made 39 visits at major corporations in the US during the 1979-80 period. In addition, 23 on-campus visits were arranged, including both initial visits and follow-up visits. An additional 114 companies are assigned to Committee members, and visits to many of these companies are anticipated in coming months.

Since the National Business Committee was organized specifically to amplify corporate solicitations during the Leadership Campaign, a brief overview of its accomplishments is of timely interest. A Committee of 14 was established in October 1976, chaired by Mr. Terrell, who continued as chairman throughout the Leadership Campaign. In the summer of 1977 the Committee was expanded to its current size. During the period October 1976, through June 1977, 65 company visits took place, resulting in commitments totaling \$486,000. During the past three years, Committee members and other alumni have played active roles in arranging 202 company visits and the submission of proposals totaling \$11,494,060, which have resulted in commitments to date of \$4,688,560. For the entire period of its existence, the Committee has made 267 corporate visits, with commitments totaling \$5,174,560. These figures include 25 Industrial Liaison Program memberships and two Associates Program memberships. Several additional proposals for membership are under active consideration.

The success of the National Business Committee clearly shows the desirability of continuing this activity in the post-Campaign period. Plans are under way to reconstitute the Committee into an even more potent force of key alumni who will be able to maintain the present momentum and identify and develop additional possibilities for support. In addition, experience thus far shows that many alumni who do not find it possible to become official Committee members are, nevertheless, very willing to help with selective corporate solicitations. In fact, about half the accomplishments of the NBC have resulted from the efforts of alumni who are not formal members of the Committee. Concerted attention will be given to the identification and development of more such alumni to maximize the possibilities for alumni support. At year-end, staff support was increased with the appointment of Jacquelyn M. Findlay, formerly Associate Director of the MIT Alumni Fund, as Assistant Director of Corporate Relations.

Development Office

The Development Office continued to serve as the main data bank for the Institute's development activities. It also identified and evaluated major donors and prospects; recommended funding strategies; coordinated development contacts by senior officers, deans, faculty members, and Resource Development staff; and responded to numerous internal and external queries about potential support from private sources. Over the year, the office also expanded contacts with faculty members and assisted them with funding needs.

In addition, in planning post-Campaign operation, the office organized an information-processing center for more effective record keeping on prospects and donors. As the facility develops, it also will provide a central working library of key research documents and become the basis of a future electronic mail system.

Foundation Support

Staff responsibility for foundations remained in the Development Office, under the direction of Dr. Vincent C. DeBaun and G. Rodger Crowe. With the counsel of the Provost, they maintained and expanded contact with numerous faculty members in recommending, planning, and carrying out visits to private and corporate foundations in support of academic programs.

Communications

The creation of an Office of Communications, scheduled to begin full operation on July 1, 1980, was announced within Resource Development at the end of 1979. Communications merges the activities of Proposals and Publications and Donor Relations, under the direction of Deborah J. Cohen. The announcement of the new organization was the first step in a major effort to substantially increase the level of contact between MIT and the growing population of individual, corporate, and foundation donors.

During the past year, the Communications staff prepared proposals and publications in support of the fund-raising activities of MIT's senior officers, faculty members, and Resource Development staff. A revised and expanded version of *Endowed Professorships at MIT: A Brief History* was published in September, and included a number of new chairs established during the Leadership Campaign.

Communications staff members also continued to assist senior officers, faculty, and staff in maintaining contact with donors. Several luncheons were arranged for donors of scholarship funds and students receiving scholarship support.

With the close of the Leadership Campaign, plans proceeded for special mailings to alumni and for sending tokens of appreciation to Campaign volunteers.

Individual Giving

With the completion of the Leadership Campaign, planned giving will become an increasingly important mechanism for private support. The Office of Planned Giving and Legal Affairs expects

to be involved in an expanded range of activities, in close cooperation with both Resource Development staff and the MIT Alumni Association and Alumni Fund.

Gifts and bequests from alumni and friends totaled \$12,764,818 this year. The Planned Giving Program, which encourages major capital contributions through outright current gifts, gifts in trust, and bequests through individual programs of giving, generated 45 percent of this total. The Program and the Office of Planned Giving and Legal Affairs are under the direction of D. Hugh Darden, assisted by Associate Director Thomas R. Henneberry. The following table details the results of the Program.

	<u>Donors</u>	<u>Dollars</u>
Outright gifts generated by Program	48	\$1,054,263
Separately invested unitrusts	5	597,947*
William Barton Rogers Pooled Income Fund	31	645,324
Receipts from bequests, testamentary and other trust arrangements	69	3,422,240
TOTAL	<u>153</u>	<u>\$5,719,774</u>

* In addition, 18 new trusts were established outside MIT and are appropriately reflected in the trust table below. Some of these are in process of funding and it is projected that the total of these when fully funded will be on the order of \$1,666,569.

As of June 30, 1980, there were on record with the Institute 1,150 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, 36 estates and outside trusts were closed and fully distributed (amount included in table above). Irrevocable trusts totaled 251 (see table below).

	<u>Number</u>	<u>Dollars</u> <u>(Current Market Value)</u>
Trusts held by MIT	121	\$11,924,038
Trusts held outside MIT	130	22,815,292
TOTAL	<u>251</u>	<u>\$34,739,330</u>

During the year, two trust funds held by the Institute totaling \$134,114 were closed and transferred over free of trust for Institute purposes.

During the month of September, a new booklet, *A Commentary on Life Income Plans at the Massachusetts Institute of Technology*, was mailed as part of the continuing series of Class Estate Secretaries mailings to more than 23,000 alumni graduated 25 or more years. Several significant gifts, both outright and in trust, can be directly attributed to this mailing. Some 30 individuals who responded to the mailing have been specially designated for personal follow-up.

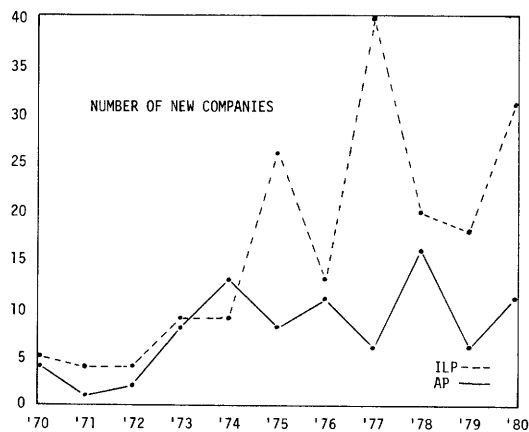
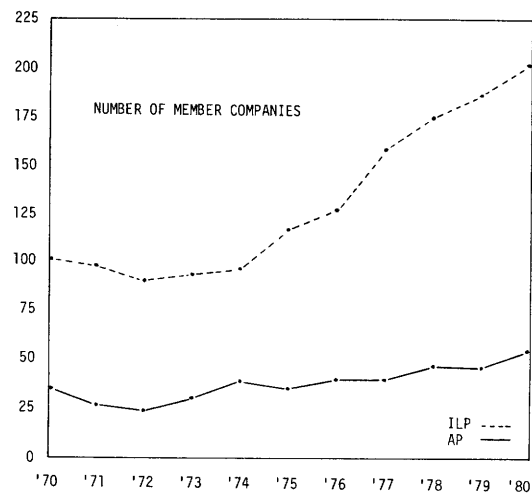
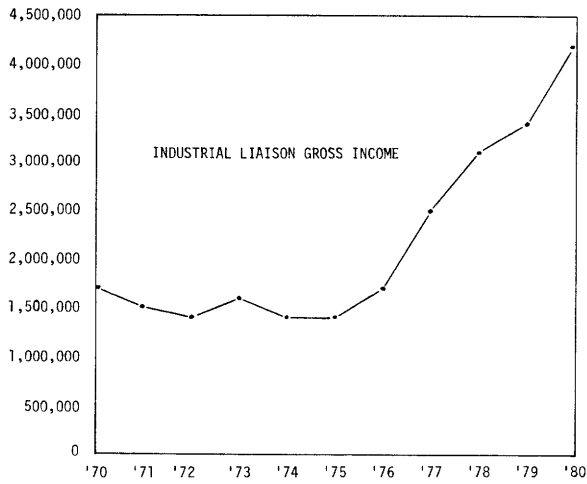
Nine planned giving luncheon meetings were held during the year at various geographic locations. These were conducted in cooperation with District Directors and especially with Nancy Russell, Associate Director of the Alumni Fund. Several gifts in trust are now in negotiation as a result of these, and two substantial outright gifts were realized directly from these meetings. An additional 18 prospects have been identified for personal follow-up as a result of these meetings.

Monitoring of Federal tax law and regulatory rules was continued, though no special actions were needed in this area. Advice and counsel on a wide variety of legal matters regarding gift arrangements and institutional management were provided to various officers of administration, donors, and others.

Beginning at midyear, cooperative plans were developed with District Directors and the Alumni Association looking to greatly increase activities with the individual donor community after the close of the Campaign. The plans included a series of seminars for administrative officers and staff on the tax effects of giving, announced at the end of the year. In cooperation with District Directors and the Alumni Association, plans for a substantial increase in the number of planned giving luncheons were developed. By year-end, plans to announce the opening of a new pooled income fund, the Maclaurin Fund, were well advanced.

Industrial Liaison Program

The Institute's Industrial Liaison activities continued their pattern of rapid growth during the past year. By year's end both the Industrial Liaison Program (ILP) and the Associates Program (AP) had reached new highs in membership, with 202 and 55 member organizations, respectively. During 1979-80 a total of 31 organizations became ILP members, the second highest number to join in any one year. (The largest growth occurred in 1976-77 when 40 companies joined the program. In that year, the ILP opened its office in Tokyo with 18 Japanese companies joining the program.) Also during the past year, 11 new companies joined the AP. Gross revenues for 1979-80 were \$3,854,740 for the ILP, and \$361,375 for the AP, yielding a combined revenue of \$4,216,115. This represents an increase of 23 percent from the \$3,433,650 total for 1979, and is the first time the combined gross income from these programs has exceeded the \$4,000,000 level. The number of ILP companies in Europe reached 36, an increase of 9, and a new high; and Japanese members totaled 24, a decrease of 1. The program trends for the past decade are summarized in the figures below:



The most important service offered by the liaison program is access to the Institute's faculty and staff. Such interactions continued to increase in the 1979-80 year with some 700 company visits to the campus involving over 2,000 visits to faculty and staff. In addition, there were some 300 faculty and staff visits and 400 liaison officer visits to member company locations.

The liaison programs' publications activities continued at a strong level during the year. Over 10,000 requests for MIT preprints, research reports, and other information were received from member companies, and over 40,000 individual documents were mailed out. In January the Publications Unit moved to larger space in Building 39, freeing space for the additional liaison officers needed to serve the increasing number of member companies. In spite of a net gain in space, the liaison programs continue to have serious space problems because of their rapid growth.

Nineteen symposia were presented by MIT faculty members during the past academic year with a total attendance of 1,750. All but two of these conferences -- "Intelligent Videodiscs and Their Applications" and "Composite Structures Technology in the European Aircraft Industry," which were presented in Los Angeles -- were held on the MIT campus. Three of the symposia attracted especially significant industrial attention: "Materials Research Program at MIT," "How Micro-processors are Changing Product Design," and "Office of the Future: Where Are We Going? How Will We Get There?" In addition, 18 seminars were presented in Japan for ILP Japanese member companies, by some 16 MIT faculty and staff members. Total attendance at the Japan meetings approached 500. In addition, while in Japan in March, Chairman Johnson and President Wiesner addressed representatives of many of our Japanese member companies.

As part of the ILP's efforts to expand service to its European companies, two successful intensive short courses were presented in Brussels: "Management of Research, Development, and Technology-Based Innovation" with Professors Thomas J. Allen, Edward B. Roberts, and James M. Utterback; and "Fermentation Technology," with Professors Daniel I. C. Wang, Charles C. Cooney, and Arnold L. Demain, and guest lecturers Dr. David A. Hopwood, Head of the Department of Genetics at John Innes Institute, Norwich, England, and Dr. Arthur E. Humphrey, Dean of Engineering and Applied Science and Professor of Chemical Engineering in the Department of Chemical and Biochemical Engineering at the University of Pennsylvania. Attendance at the two courses was 59 and 79, respectively.

An outstanding feature of the year was a special conference, "The Decades Ahead: An MIT Perspective (A Symposium for Senior Executives)," initiated and planned by the ILP. This extremely successful meeting, held on the campus from June 24 through 26, attracted over 300 senior leaders from industry and government. Twenty-eight MIT faculty members, representing all five of the Institute's Schools, discussed topics in four major areas: the economy of the 1980s; the technological and organization impact of computers and communication; materials resources and technology; and biology -- the coming industrial revolution. The proceedings of this meeting will be published during the coming year.

The continued success and growth of both the ILP and AP are due to the cooperation of the more than 650 MIT faculty members who participate in the Institute's industrial liaison activities and are the focal point of the two programs. This report would not be complete without a heartfelt word of appreciation to them.

Sustaining Fellows

The MIT Sustaining Fellows program was formally announced at the annual meeting of the Corporation Development Committee on October 11, 1979. The program is designed to recognize and involve individuals whose support, encouragement, and commitment to the goals of MIT make them valued members of the MIT community; and to draw into MIT others who want to share in and support the Institute's efforts. Over 400 alumni and friends of the Institute became Founding Members or Founding Life Members during the program's first year of operation.

During the year, various members were invited to be special guests at a number of MIT symposia, as well as at a luncheon with Dr. Wiesner in Los Angeles, organized by Sustaining Fellows Frank Wyle, Class of 1941, and Leonard Mautner, Class of 1939. In addition, several Boston area members attended the opening of the Hayden Gallery Exhibition "Arts on the Line," and two one-act operas produced under the sponsorship of the William L. Abramowitz (Class of 1935) Memorial

Fund of MIT's Department of Humanities. The first annual gathering of the membership is planned for fall 1980. Sustaining Fellows will continue to be invited to special events and will be in close contact with senior officers and faculty of the Institute.

Corporation member Breene M. Kerr, Class of 1951, serves as chairman of the MIT Sustaining Fellows, and the Chairman of the Corporation and the President of MIT serve as honorary chairmen. Professor Elias P. Gyftopoulos serves as the faculty chairman of the program. Eric C. Johnson is the executive officer responsible for the program, and is assisted by E. Barbara Lewis. In addition, several of the Sustaining Fellows have agreed to serve on a sponsoring committee to assist in enlisting new members and organizing events for Sustaining Fellows away from the Cambridge area.

Staff Changes

During the year, Nelson C. Lees was appointed Director of Resource Development, with broadened responsibilities.

As the Campaign came to a close, two of the five District Officers terminated their MIT employment: Arnold H. Singal in January and Robert E. Gorman in April. Mr. Singal had held several important assignments since joining the MIT staff in 1968; Mr. Gorman had joined the staff in 1977 for the duration of the Campaign. We are indebted to them for their distinguished support of the volunteers throughout the Campaign effort.

In September of 1979, Dr. Vincent C. DeBaun joined the Institute as Director of the Development Office. Later in the year G. Rodger Crowe was appointed Associate Director.

A number of staff changes occurred in the Office of Communications: Deborah J. Cohen was appointed Director; Martha L. Bertrand was appointed Senior Associate; Ellen N. Hoffman was appointed Senior Staff Writer/Assistant to the Director; and Katharine C. Jones was appointed Senior Staff Writer. D. Steven Blum, Assistant Staff Writer during the final two years of the Leadership Campaign, left the Institute at year-end to pursue graduate study.

Barbara V. Zeilenga, Manager of Donor Relations, resigned from the Institute, effective June 30, after 10 years of service to the Resource Development organization. Her presence will be greatly missed.

In the Office of Planned Giving and Legal Affairs, Thomas R. Henneberry was appointed Associate Director.

After many years of loyal service to the Institute, James T. King, Manager of Corporate Support Programs, resigned at year-end to accept important responsibilities at the Massachusetts College of Pharmacy.

Several changes occurred among Industrial Liaison staff. George K. Sankey became Assistant Director of the ILP, while retaining his appointment as Director of the MIT-ILP Japan Office in Tokyo. In the Associates Program, Gary K. Roberts was appointed Assistant Director, succeeding John T. Preston who became an Industrial Liaison Officer in the ILP. Also in the ILP, Dr. Kay Tamaribuchi was appointed Industrial Liaison Officer at the beginning of the year and was later promoted to Assistant Director. Jane E. Martini and Laura S. Stout were appointed Industrial Liaison Officers, and Susan I. Shansky was appointed Publications Supervisor. Arturo A. Rosales, Assistant Director of the ILP, resigned to become Senior Project Engineer at Hughes Aircraft Company in Los Angeles; and at year's end Dr. Shirley M. Picardi, also Assistant Director of the ILP, took a leave of absence to enter the Sloan Fellows Program at MIT's Sloan School of Management.

In the MIT Sustaining Fellows program, E. Barbara Lewis was appointed staff assistant.

Summary

I wish to express sincere gratitude to all those who have worked so hard during the past year to bring the Leadership Campaign to a fine conclusion: the senior officers, the Campaign

Vice President, Resource Development

cochairmen, my colleagues in the administration and on the faculty, the members of the Volunteer Leadership Appeal and National Business Committee, and the Resource Development staff. Once again, my special thanks to Nelson C. Lees, whose commitment to the Campaign and the Institute were recognized by his receipt of the Gordon Y. Billard Award on Technology Day, June 1980.

SAMUEL A. GOLDBLITH

Lincoln Laboratory

During the past year, Lincoln Laboratory has continued in its role as a Federal Contract Research Center for the development of advanced electronics, with agencies of the Department of Defense (DOD) -- the Air Force, Army, Navy, and the Defense Advanced Research Projects Agency -- supplying 88 percent of the Laboratory's budgetary support. The Federal Aviation Administration and the Department of Energy provide most of the non-DOD support. The size of the Laboratory has remained essentially constant. In fiscal year 1980 the operating budget was \$140 million, supporting the efforts of 818 professional staff -- 75 percent of whom hold advanced degrees. The level of staffing for defense work is fixed by agreement between Congress and the Department of Defense and is not expected to change during the next few years.

There were a number of changes this year in the Laboratory Steering Committee and Division leadership. Dr. Glen F. Pippert and Paul Rosen were appointed Division Heads of the Optics and Engineering Divisions, respectively. Appointed Associate Division Heads and members of the Steering Committee were: Dr. Theodore Bialy, Data Systems; Dr. Louis C. Marquet, Optics; Milan Vlajinac, Engineering; and Dr. Herbert Kottler, Aerospace. William P. Delaney was transferred as Associate Head from Radar Measurements to Surveillance and Control. Professor Robert H. Rediker, Head of Optics, and Professor Alan V. Oppenheim, Associate Head of Data Systems, resigned from these positions to devote more time to academic activities. Dr. John F. Hutzenlaub, Head of Engineering, retired after 28 years of service to the Laboratory, and Verne L. Lynn, Associate Head of Surveillance and Control, has requested leave of absence to take a position in government.

The Space Surveillance Group in the Laboratory Aerospace Division has been engaged for several years in the development of low-light-level optical sensors and related control systems. The principal goal has been to provide the United States Air Force (USAF) with the means to detect and track artificial earth satellites at distances beyond the search capabilities of existing radars. The Lincoln Experimental Test System in New Mexico has provided the baseline design for the USAF Electronic Systems Division to procure five globally deployed systems. The program is known as GEODSS, for Ground-based Electro-Optical Deep Space Surveillance.

The GEODSS optical sensors, which comprise TV-like cameras on modest size telescopes (about one meter aperture), can easily detect an object which has a surface no larger or brighter than this page at a distance of some 40,000 kilometers, where most of the geostationary communications and weather satellites reside. The sensors and associated processors discriminate the satellites from stars by their apparent motion through the star field. These techniques have recently been applied to the detection and refinement of positional data for small asteroids orbiting between Mars and Jupiter, thus demonstrating the feasibility of an efficient search for earth-orbit-crossing asteroids or other celestial objects which may in the near future come in close proximity to our planet.

A basic attribute of the new GEODSS sensors is high quantum efficiency. The latest electro-optical charge coupled devices (CCDs), such as those developed by the Microelectronics Group of the Lincoln Solid State Division, are within a factor of two or three of the perfect conversion of photons from the light image to photoelectrons for detection. The CCDs are therefore 100 to 1,000 times faster than the best photographic film used in astronomy. The high sensitivity and real-time digital processing techniques allow rapid simultaneous measurement of light curves and color indices for the myriad stars in the field of view. With many CCD chips in a mosaic pattern at the focal plane of the GEODSS telescope, it should be possible to survey the sky in a few weeks to a limiting magnitude that usually requires several years.

Recently, Lincoln has completed development of some high-speed digital signal processing systems which significantly advance the state of the art in high-performance radar signal processing. These systems were designed by Lincoln and fabricated by industry. The first system is a digital convolver which performs matched filtering of radar returns. The filtering is based on Fourier transformation of the digital radar signal, multiplication of the resulting signal spectrum by the desired filter function, and then inverse Fourier transformation of the spectral data. The underlying Fourier transform is accomplished by the efficient "fast Fourier transform" algorithm, having a size of 16,384 points. This transform size allows the matched filtering of signals with time-bandwidth products up to 16,384. These transforms can be performed at a throughput rate of one per 137 microseconds. For comparison, the same processing requires approximately two seconds of dedicated CPU time on an IBM 370 computer. The second digital signal processing system is a demodulator converter unit which contains a synchronous detector and two high-speed analog-to-digital converters, which can continuously digitize data to 10-bit resolution at a rate of 60 megasamples per second (Ms/s). This system converts an analog bandpass signal to two 60-Ms/s streams of 10-bit digital words. This combination of sample rate and word length is significantly better than has been achieved with other analog-to-digital converters.

In addition to the two systems discussed above, Lincoln has developed two extremely high-speed digital components: a serial-to-parallel converter and the complementary parallel-to-serial converter. The serial-to-parallel converter takes a single 900-Ms/s bit stream and converts it to eight parallel 112-Ms/s bit streams. This device, when used in conjunction with a high-speed, analog-to-digital converter now under development and a memory based on commercially available components, has the potential of allowing the digital acquisition of extremely wideband (900-MHz) data. The parallel-to-serial converter provides the complementary function of taking eight channels of data at 100 Ms/s and converting it to one channel at 800 Ms/s. This device has the potential of allowing the digital generation of high-speed (800-MHz) signals.

A new type of transistor has been conceived and constructed at the Laboratory whose configuration is reminiscent of that of the vacuum tube, and which has a potential for a much higher maximum frequency of oscillation or amplification (up to 1000 GHz) and far lower power delay product (approximately 0.3 fJ) than existing solid state devices. This concept has recently been demonstrated in a gallium arsenide device, called the permeable base transistor (PBT). The unique fabrication feature of the device is an extremely fine (0.3 micrometer) tungsten grating which is imbedded in and forms Schottky barriers with single crystal n-type gallium arsenide. The current flowing from the emitter to the collector is controlled by the electric potential applied to the tungsten grating, which functions as the transistor base. The name of the device refers to the flow of current over a potential barrier established by the fingers of the base.

The PBT is the basis for a Laboratory program to develop an integrated 10-GHz bandwidth packet radio transceiver with a selectable center frequency of as high as 100 GHz. Also, a study has been initiated of the use of the PBT as a centimeter-wavelength power amplifier for military satellite communication terminals. In addition to use for microwave oscillators and amplifiers, the device is expected to be a key element in very-high-speed large-scale digital logic circuits.

The development of the PBT and other advanced solid state devices grows out of a continuing program at the Laboratory in submicrometer technology. The techniques being developed in this program include scanning electron beam lithography, X-ray lithography, ultraviolet and holographic lithography, ion beam etching, plasma etching, reactive ion etching, evaporative shadowing, and electro-plating.

A number of Laboratory projects employ digital spectrum estimation techniques to provide the best possible spectral information from a limited amount of data. For example, a small number of samples from a coherent pulsed radar must be spectrally analyzed to extract velocity information in the form of measured Doppler shifts. Also, spacial spectrum analysis is important for arrays of sensors. The number of sensors and the array aperture are limited by allowable size and cost, and one often wants to provide resolution in excess of the classical antenna beamwidth. The use of arrays of microwave antennas, microphones, or seismometers for direction finding can in each case be formulated as a spectrum analysis problem.

Because of the importance of spectrum estimation, the Laboratory is continuously investigating, testing, and applying new techniques in this area. One of these new techniques is the maximum

entropy or autoregression modeling method in its various forms. Theoretical work, algorithm development, and tests of performance of these methods are being actively pursued. Applications which have recently been investigated and which show promise are radar imaging, using estimates of Doppler shifts from different parts of a target; multipath analysis in low-elevation tracking, using small vertical microwave antenna arrays; and direction finding with fractional beamwidth accuracy. Other spectrum analysis techniques being investigated for these purposes include direct maximum likelihood estimation of amplitude and frequency of multiple sine-waves in noise; methods based upon linear unbiased least squares estimates for sine-waves or plane waves in noise; and other kinds of entropy-based methods.

For the past several years, under sponsorship of the Federal Aviation Administration (FAA), the Laboratory has been developing a new radar beacon surveillance system for air traffic control. By the use of interrogations addressed to individual aircraft, this new system, termed the Discrete Address Beacon System (DABS), eliminates the self and intersite interference effects which limit the reliability and accuracy of the existing Air Traffic Control Radar Beacon System (ATCRBS). Combined with monopulse-on-receive and improved signal processing to reduce residual interference, discrete addressing of interrogations results in greatly improved tracking of aircraft, a prerequisite for automatic conflict detection and resolution. In addition, the discrete addressing allows digital messages to be transmitted between ground stations and individual aircraft, thereby providing a flexible ground-air-ground data link communication system.

After several years of development and test at the Laboratory, prototype DABS ground stations and aircraft transponders were built for the FAA by industrial contractors working under the technical guidance of the Laboratory. These equipments have provided the basis for an extensive test and evaluation of DABS at the FAA's National Aeronautic Facilities Experimental Center. Based on the successful results of these tests, the FAA is planning to initiate operational implementation of DABS in the early 1980s. Complementing the US national program, there is strong interest in DABS in the United Kingdom, France, Italy, and the USSR. In particular, the United Kingdom also has an operating experimental ADSEL station (the UK name for DABS).

As an extension of the DABS effort, the Laboratory is presently developing for the FAA an aircraft collision avoidance system termed BCAS (beacon collision avoidance system). A BCAS-equipped aircraft senses the range and altitude of proximate aircraft by interrogating and receiving replies from their ATCRBS or DABS transponders. BCAS provides substantially greater protection than the previously proposed airborne collision avoidance systems (ACAS); since BCAS warns of conflict with any ATCRBS or DABS transponder-equipped aircraft, whereas ACAS provided warning only if the conflicting aircraft was also ACAS-equipped.

For the Department of Energy, two large experimental photovoltaic (PV) power systems were installed during the past year in Utah and Ohio. In August 1979, a 15-kilowatt peak power system was installed at radio station WBNO, Bryan, Ohio. It provides electricity for the station's AM transmitter and other electrical loads in the studio. The system utilizes a microprocessor-based control system which routinely provides unattended, hands-off operation of the power system. In a dedication ceremony on June 7, 1980, the world's largest PV system (100 kilowatts peak power) was turned on at the Natural Bridges National Monument, which is located in a remote region of southeastern Utah. The Laboratory provided the system design, monitored contractor activity, and now is evaluating the performance of the system. Because of its remoteness, Natural Bridges is not connected to an electric utility grid, and the PV system operates in a stand-alone mode. It contains sufficient electric battery storage to meet the entire electricity demand of the Monument for approximately two days of cloudy weather. Beyond this, the diesel generators, which formerly operated continuously to provide electric service for the Monument, will be used. On an annual basis, it is anticipated that the diesel generators will be required for less than 10 percent of the total electric energy used by the Monument.

These PV power systems complement eight other experimental systems which the Laboratory has installed in six states, the systems ranging in size from tens of watts to 25 kilowatts. Without exception, these experimental units have demonstrated that PV power systems are extremely reliable. In addition, based on data from some of the earlier systems such as the Mead, Nebraska, 25-kilowatt agricultural experiment, the systems have exhibited very little degradation in power output over evaluation periods as long as three years.

The Laboratory's responsibility in development and evaluation of PV power systems is now directed toward residential applications. Residential systems represent an extremely large and possibly early (pre-1990) market, which could be economically competitive with electricity supplied by the US electric utility grid from fossil-fuel-fired plants. This assumes continued fossil fuel price increases and continued price reduction successes in the Federal PV Program. The US Department of Energy has designated the Laboratory as the lead organization to develop and demonstrate the technology required to attain this goal, although PV cell and module development remains the responsibility of the Jet Propulsion Laboratory. To carry out this important mission, Lincoln Laboratory has prepared and is implementing for the Department of Energy a multi-year PV residential plan which calls for extensive development and evaluation of residential PV systems in various geographical and climatic regions of the US. To provide on-site energy storage for residential PV systems, the Laboratory is actively pursuing the development of advanced flywheel energy storage systems. The goal of this activity is to develop an economically competitive alternative to lead-acid battery storage, which presents many problems for residential usage.

Nearly all Laboratory activities require computational support. The Laboratory's first central computer facility was installed in the summer of 1957, and the work load has since grown at an annual rate of 20 percent (compounded) or expressed otherwise it has doubled about every four years. This spring, the Laboratory took another step to meet the growing demand for computer service by the installation of an Amdahl 470 V/7, which operates at a speed of about six million instructions per second (MIPS). This new computer is architecturally compatible with the IBM 370/168, which it replaced, allowing the use of the same operating systems and permitting application programs to be run without modification. Projecting ahead, the new computer with available upgradings is expected to become overloaded by about 1984. We expect the general purpose main-frame manufacturers by then to be offering systems in the 15-20 MIPS range, in time to relieve the seemingly never ending pressure of computer usage growth.

WALTER E. MORROW, JR.

Treasurer of the Corporation

Financial Statements

The financial statements summarize the finances of the Institute during the fiscal year 1979-80 and at the close of the year on June 30, 1980.

Schedule A

The Statement of Revenues and Funds Used to Meet Expenses of Current Operations for the year ended June 30, 1980 with comparative totals for 1979 displays the expenses and the revenues and 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, 1980 with comparative totals for 1979 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, 1980 with comparative totals at June 30, 1979 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, 1980 with comparative totals for 1979 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, 1980 with comparative totals for 1979 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, 1980 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.

Glossary

University Fund Accounting

A background description of fund accounting, so important in understanding college and university finances, can be found following the Glossary.

Operations (Schedule A)

Total operating expenses in 1979-80 were \$418,144,000, an increase of 17 percent over the 1978-79 total of \$357,409,000. Total operating revenues and funds used to meet these expenses rose to \$412,352,000, an increase of 17.2 percent over the 1978-79 total of \$351,844,000. The additional need for unrestricted revenues and funds required to bring operations into balance was \$5,792,000 in 1979-80 compared to \$5,565,000 in 1978-79. This requirement in 1979-80 was met entirely from current year revenues of: 1) \$1,468,000 from the net Use of Facilities Allowances derived from sponsored research programs, 2) \$1,038,000 from Patent Revenues and 3) \$3,662,000 from Unrestricted Gifts, Grants, and Bequests. These sources totaled \$6,168,000 and all amounts received in these categories were availed of to meet expenses, except for \$376,000 which was the excess of unrestricted funds received over the funds required to balance. This excess is being held to support future operations. There was also \$334,000 of additional Use of Facilities Allowances reserved for continuing capital needs, primarily in the area of utility plant renewal and the expansion of utility distribution lines for air conditioning and heating. Furthermore, a large unrestricted bequest of \$610,000 was added to Funds Functioning as Endowment for general purposes.

It is worthy of note that instruction and unsponsored research increased 14 percent, the direct expenses of departmental and interdepartmental sponsored research increased 16 percent, and the direct expenses of Lincoln Laboratory increased 25 percent over the previous year. All other expenses required to support those activities increased by 12 percent. It is also significant that no Funds Functioning as Endowment have been required to bring operations into balance during the past four years and no Other Fund Balances have been required for three years. It is also a sign of improvement that the full investment income on the Research Reserve was added to principal for the third time in as many years and a large addition was made to the Reserve of Investment Income for Distribution to Funds. The funds available from operations also contributed significantly to the acquisitions from the investment portfolio of real estate for educational plant which are necessary to accommodate the growing need for space for both instruction and research activities.

Looking ahead, the Institute would like to be in balance so that no demands are made on three important elements of unrestricted income: namely, Use of Facilities Allowances, Patent Revenues, and Current Gifts, Grants, and Bequests. This was the case for many years prior to 1970. During the past decade, however, nearly all of the funds from these sources have had to be used for current operations. A financial objective is to have these funds available for new programs, capital needs, and other purposes which will strengthen the Institute's capital base.

A five-year history of the additional need for unrestricted revenues and funds to bring operations into balance, and the source of the funding used to meet the need is shown in the following table. This table presents the years 1976-78 on a basis comparable to 1979 and 1980 shown at the bottom of Schedule A.

(In thousands of dollars)	1980	1979	1978	1977	1976
Additional need for unrestricted revenues and funds	<u>\$5,792</u>	<u>\$5,565</u>	<u>\$5,875</u>	<u>\$5,801</u>	<u>\$6,493</u>
Additional need for unrestricted revenues and funds met from:					
Use of facilities allowances	\$1,468	\$1,458	\$1,433	\$1,308	\$1,220
Patent revenues	1,038	756	810	629	457
Current gifts, grants, and bequests	<u>3,662</u>	<u>3,407</u>	<u>3,700</u>	<u>3,738</u>	<u>2,216</u>
Total additional current revenues	\$6,168	\$5,621	\$5,943	\$5,675	\$3,893
Less: Funds available for future operations	<u>376</u>	<u>56</u>	<u>68</u>	<u>0</u>	<u>0</u>
Net additional current revenues used	\$5,792	\$5,565	\$5,875	\$5,675	\$3,893
Other fund balances	0	0	0	126	1,201
Funds functioning as endowment	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>1,399</u>
	<u>\$5,792</u>	<u>\$5,565</u>	<u>\$5,875</u>	<u>\$5,801</u>	<u>\$6,493</u>

Gifts

Gifts, grants, and bequests in 1979-80 and in 1978-79 were as follows:

	1979-80	1978-79
Gifts for endowment	\$ 9,217,000	\$ 8,354,000
Gifts for buildings	6,964,000	6,065,000
Gifts for current and future use — invested	9,313,000	10,338,000
Other gifts for current use	<u>5,888,000</u>	<u>5,823,000</u>
Total gifts to funds	\$ 31,382,000	\$ 30,580,000
Grants-in-aid	<u>2,459,000</u>	<u>3,364,000</u>
Total	<u>\$ 33,841,000</u>	<u>\$ 33,944,000</u>

The total of \$33,841,000 is within 1 percent of the total of \$33,944,000 received in the previous year. This is 67 percent higher than five years ago and has exceeded \$31,000,000 in each of the past three years.

The MIT Leadership Campaign was successfully concluded in April 1980, with \$250,200,000 of gifts and pledges received, 11 percent higher than the goal set five years ago. It is most gratifying that the momentum of the Campaign has continued. Significant new gifts and pledges have been received recently, together with a continued large inflow of gifts resulting from pledges made during the Campaign.

Gifts for endowment set a new yearly high and reflect both the significant funding for several endowed professorships and continued support for endowed scholarships and other purposes.

Gifts to buildings increased and reached the second highest total on record. These gifts include the funding for the Max C. Fleischmann Brain Sciences Center and the structure that will house the Nabisco Laboratory in the Plasma Fusion Center. There

was continued important support received for the Whitaker College of Health Sciences, Technology, and Management, the new Athletics Facility, and the new undergraduate dormitory on the West Campus.

The gifts for current and future use — invested include unrestricted gifts of \$3,662,000, of which \$949,000 was in bequests. Unrestricted gifts increased because of both an increase in bequests and an increase in gifts from alumni and friends. Gifts to life income plans which are also included in the Gifts for Current and Future Use — Invested declined by \$3,009,000 from the unusually high amount in the previous year which was favorably affected by a single large gift. Gifts to life income plans provide income to designated beneficiaries for life, and the income and principal becomes available for the purposes of the Institute only on the termination of these income interests. If gifts to life income plans are excluded, total gifts and grants-in-aid for Institute purposes increased by 10 percent above the previous year.

The gifts reported by the Alumni Fund totaled \$6,318,000, a new high, which resulted from a significant increase in the average gift received and in the number of donors. These gifts are included in the various categories of gifts listed above as received. The other gifts for current use include gifts restricted as to purpose used primarily for academic programs and student aid.

Grants-in-aid are support for designated research activities and declined from the previous year.

Funds

The book value of the funds was \$614,723,000 on June 30, 1980 as compared with \$583,005,000 on June 30, 1979.

	1979-80	1978-79
Endowment and similar funds:		
Income for unrestricted purposes		
Endowment	\$ 50,372,000	\$ 49,341,000
Funds functioning as endowment	31,004,000	30,311,000
Income for restricted purposes		
Endowment	109,330,000	101,036,000
Funds functioning as endowment	70,812,000	69,634,000
Investment income for distribution to funds ..	15,000,000	15,000,000
Net realized gains from investments	<u>35,245,000</u>	<u>34,941,000</u>
Total endowment funds	\$311,763,000	\$300,263,000
Building and expendable funds	66,591,000	69,098,000
Expended plant funds	189,214,000	172,444,000
Investment income for distribution to funds — current invested	11,543,000	8,578,000
Other funds	<u>35,612,000</u>	<u>32,622,000</u>
Total funds	\$614,723,000	\$583,005,000

The increase of \$31,718,000 in funds resulted primarily from the retention of gifts for investment and the expenditure of designated gifts and other funds for academic plant. Total endowment funds increased by \$11,500,000 and resulted both from the retention of gifts to endowment and the designation by the Institute of a large bequest of \$610,000 as funds functioning as endowment for unrestricted purposes. The improvement in financial operations has again permitted the designation of large unrestricted bequests to endowment, rather than to current operating expenses.

The increase of \$304,000 in net realized gains from investments resulted from the sale of equities at prices above book value which more than offset the moderate net loss on sales of fixed income securities and real estate.

The building and expendable funds decreased by over \$2,000,000 because of a drawdown of building funds by more than \$14,000,000 for the construction of new educational plant. Excluding building funds, the expendable funds increased and reflect the continued inflow of gifts for academic operations.

The investment income for distribution to funds — current invested increased by \$2,965,000. These funds result from the retention of the portion of investment income which exceeds the income distributed to funds.

It is important to note that funds are shown at book value and do not reflect the market value of the invested assets. Gifts to endowment funds are usually invested in market value units of Pool A in the General Investments at the time of the gift. The market value of the General Investments exceeded book value by over \$110,000,000 at June 30, 1980.

The other funds increased by \$2,990,000 because of an increase in student loan funds. There was also an increase in funds subject to life interests in income and in agency funds held for affiliated organizations.

Plant

The Institute is undergoing a major expansion and upgrading of its physical plant. Capital projects include the Whitaker College of Health Sciences, Technology, and Management Building and the new Health Services Facility on the East Campus which are scheduled for completion in September 1981. A new Athletics Facility on the West Campus is nearing completion and a new house for undergraduates at 500 Memorial Drive is now in the construction stage. The funding of these projects was completed in June through a \$38,000,000 bond issue of the Massachusetts Health and Educational Facilities Authority at an interest rate of 7.26 percent to be repaid over a 30-year period. A new chilled water plant to eventually serve the entire East Campus will be completed within the next year. The funding of this project is through assessments to facilities served by the plant.

Major renovations of existing buildings are taking place over the entire campus. The Webster Building project on the East Campus is now well under way and the expected completion date is spring 1981. This will house the Energy Laboratory, the Center for Policy Alternatives, several of the research elements of the Sloan School of Management, as well as many other interdisciplinary research activities. The rehabilitation and upgrading of animal care facilities has continued at a brisk pace. The continued expansion of the Plasma Fusion Center on Albany Street requires increased space and the gift from Nabisco, Inc. of a building in the midst of the Plasma Fusion Center — National Magnet Laboratory complex is an important addition to our research facilities. An upgrading of the Spectroscopy Laboratory has begun in response to a resurgence of interest in that field, and has been supported by a major grant from the National Science Foundation. A gift from a private donor has initiated a project to provide new facilities for the Human Mechanics and Rehabilitation Laboratory on the first floor of Building 3. Further funds were put into the combustion facility on the main campus to provide for the handling of coal in carrying out the research purposes of that activity. Finally, the replacement of the Kresge Auditorium roof at a cost of approximately \$1,000,000 has been one of the major facilities renewal projects during the past year.

The Institute expects the demand for building space to continue, particularly as it responds to national needs in new areas of research.

The book value of educational plant was \$230,488,000 at June 30, 1980, up from \$208,195,000 on June 30, 1979.

Total mortgage indebtedness at June 30, 1980 was \$68,002,000 consisting of \$9,797,000 of Federal government loans, \$58,130,000 financed through the Massachusetts Health and Educational Facilities Authority, and \$75,000 of other loans.

Investments

The year-to-year change in the endowment and other investments is shown in the following table.³

	June 30, 1980		June 30, 1979	
	Book	Market	Book	Market
General Investments				
Fixed income	\$154,478,000	\$144,480,000	\$171,115,000	\$161,517,000
Equities	169,470,000	287,550,000	143,521,000	231,560,000
Real estate				
For present or future use	9,917,000	10,085,000	9,298,000	9,298,000 ¹
Other real estate	28,780,000	30,590,000 ²	32,116,000	32,916,000 ²
Total	\$362,645,000	\$472,705,000	\$356,050,000	\$435,291,000
Separately invested	34,017,000	34,766,000	31,159,000	31,803,000
Total	\$396,662,000	\$507,471,000	\$387,209,000	\$467,094,000

¹ At cost

² At values determined by professional appraisers

³ This table excludes students notes receivable and amounts due from Educational Plant Funds.

Total invested assets exceeded one-half billion dollars for the first time. There was an increase of \$40,377,000 in the market value of the portfolio in 1979-80 as compared with an increase of \$57,491,000 in 1978-79. Over three-fourths of the 8.6 percent increase in this year's market value resulted from market appreciation alone. Because of the drawdown of invested building funds to meet the expenses of construction, the gifts to endowment funds were the primary source of new funds for investment.

The market value of equities in the General Investments increased by almost \$56,000,000, a gain of more than 24 percent. Over one-half of this gain resulted from market appreciation and the remainder resulted from the continued net purchases of equities and retention of gifts of common stocks. During the past three years, the amount invested in common stocks has increased either as measured by dollars of book or market values, or as a percentage of the total investments.

During the past year, a portion of the holdings in fixed income securities was used to purchase equities. Fixed income investments have been held primarily in short- and intermediate-term maturities because of a continuing concern with the adverse effect of a rising rate of inflation on bond prices. Purchases of issues with longer maturities have generally been limited to those periods when interest rates reached levels which were favorable relative to inflation. Such a period occurred early in calendar 1980 and the bond maturities were moderately extended. Although the market indexes of bonds with long maturities showed a

significant decline during the fiscal year, the General Investments experienced an overall market loss of less than \$1,000,000 on its holdings of fixed income securities.

The holdings of investment real estate were reduced because of transfers of real estate to educational plant. The investment income from real estate increased despite a decline in the holdings, reflecting a continued improvement in the rate of return.

The investment income received during the year, after administrative expenses, was \$31,224,000 as compared to \$26,581,000 in 1978-79. This is an increase of over 17 percent and the total increase over the past three years is 58 percent. Interest rates on short-term money market instruments were at very high levels during most of the fiscal year and were an important factor in the growth of investment income. There was also a continued growth in dividend income and in the rate of return on the holdings of investment real estate. There was a drawdown of invested building funds during the year and, as a result, new funds available for investment were less than in the previous two years.

The investment income received exceeded the income distributed to funds for the fourth consecutive year. The Reserve of Income for Distribution to Funds increased by \$2,965,000, the largest increase since this reserve was established over 30 years ago. This reserve increased to \$26,543,000, a new high, and compares with \$19,394,000 only four years ago. This reserve is divided for investment purposes into current invested funds and endowment and similar funds.

The large gain in investment income occurred during a period when assets were being redeployed from fixed income securities to equities. The effect of this redeployment was to increase the market value of the investments at June 30, 1980, and hopefully in the long term as well. Investment income would have been even higher during the year if this redeployment had not taken place.

The Investment Committee has reviewed investment policies in recent years with a particular concern for the effect of inflation on both securities values and the needs of the Institute for rising investment income. One result of this review was a decision to increase the percentage of the endowment fund investments that may be held in common stocks. There is a continuing desire to seek investments that will provide income, and hopefully capital appreciation, that will increase at a rate comparable to the rate of inflation.

The rate of inflation being experienced by the Institute, and by our students, is without precedent in the postwar period. We have found the thoughtful guidance of the members of the Investment Committee, the Corporation, and the faculty of the Sloan School of Management and the Department of Economics to be helpful in evaluating investment alternatives.

Interest rates are now at levels higher than the historical long-term total return from common stocks. Unfortunately, these interest rates are not as attractive when measured against the current rate of inflation which is higher than the past experience on which our measurements of investment returns from common stocks are based.

The earnings and dividend payments of the Institute's common stock holdings have, in recent years, shown a growth rate comparable to the rate of inflation. This has also been reflected recently in higher market prices for common stocks. If this trend continues, the total return from common stocks could be more favorable than during the past decade. Over longer time periods, the return from holding common stocks has been much more favorable than bonds. The Investment Committee has sought an investment policy that would meet both the present and future needs of the Institute. The continuing commitment to invest a large portion of the endowment funds into common stocks will, we believe, help us to meet these future needs.

General

There is considerable satisfaction in having once again achieved a year of operations with a favorable balance of income over expenses. The fluctuations within a year can sometimes be dramatic, even at the Institute. The original budget for the year just completed was in approximate balance. By November of 1979 increased energy prices and other required budget adjustments resulted in an expected deficit of \$2,000,000. However, favorable investment returns and gift flows, together with several other events on the positive side, brought the Institute's budget back into a balanced position by the end of the year. The budget for the year ahead now reflects an unfavorable balance of approximately \$1,000,000. With a combination of good effort and some good fortune, it is hoped that the budget for fiscal year 1981 can also be brought into balance. To assure success, however, the financial operations should have a continued margin of revenues over expenses. The capital base, while large in numbers of dollars, is relatively small compared to the volume of operations. It is very likely that the total volume will exceed one-half billion dollars within the next two years. While the record of accomplishment, both in financial and non-financial terms, is great, the need for additional funds to carry out the basic purposes of the Institute never diminishes. The vitality of the enterprise as it enters the decade of the 1980s is good, but the need for substantial outside support to maintain it has never been greater. Despite the limitations and the problems, we find many reasons to be optimistic about the future.

Respectfully submitted,

Stuart H. Cowen
Vice President for Financial Operations

Glenn P. Strehle
Treasurer

August 25, 1980

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
STATEMENT OF REVENUES AND FUNDS USED TO MEET EXPENSES OF CURRENT OPERATIONS

for the year ended June 30, 1980
with comparative totals for 1979
(in thousands of dollars)

Schedule A

	<i>Unrestricted</i>	<i>Institute or Donor Restricted</i>	Total 1980	<i>Total 1979</i>
OPERATING EXPENSES:				
Instruction and unsponsored research	\$ 39,384	\$ 21,508	\$ 60,892	\$ 53,381
Sponsored research (Note A):				
Direct expenses:				
Departmental and interdepartmental	—	124,296	124,296	107,521
Lincoln Laboratory	—	127,347	127,347	102,279
Research administration and general expenses	2,797	648	3,445	3,540
Total expenses directly attributable to instruction and research	42,181	273,799	315,980	266,721
Expenses jointly applicable to instruction and research:				
Libraries	4,584	278	4,862	4,345
Medical	3,338	21	3,359	3,028
Plant operations and maintenance	23,307	2,318	25,625	22,452
Administration	5,888	542	6,430	5,743
Fiscal, personnel and other Institute-wide services	12,309	251	12,560	11,871
General expenses	3,956	2,500	6,456	4,838
Other instruction and research support activities	1,920	220	2,140	1,451
Student services	4,699	2,968	7,667	8,179
Other expenses	3,965	—	3,965	2,802
Scholarships and fellowships:				
Undergraduate	937	6,507	7,444	6,830
Graduate	806	6,017	6,823	5,499
Dining and Housing	420	9,321	9,741	9,037
MIT Press	—	5,092	5,092	4,613
Total operating expenses (Schedule D)	\$ 108,310	\$ 309,834	\$ 418,144	\$ 357,409
REVENUES AND FUNDS USED:				
Tuition and other related income	\$ 49,857	—	\$ 49,857	\$ 45,028
Research revenues:				
Departmental and interdepartmental	35,494	\$ 124,296	159,790	138,227
Lincoln Laboratory	7,693	127,347	135,040	109,640
Endowment income applied to operations (Schedule B)	7,197	5,154	12,351	11,654
Gifts, investment income and miscellaneous receipts for:				
Scholarships and fellowships	—	12,458	12,458	10,189
Other restricted and unrestricted purposes	2,277	26,166	28,443	23,850
Dining and Housing	—	9,321	9,321	8,643
MIT Press	—	5,092	5,092	4,613
Total operating revenues and funds used	102,518	309,834	412,352	351,844
Additional need for unrestricted revenues and funds**	5,792	—	5,792	5,565
Total revenues and funds used	\$ 108,310	\$ 309,834	\$ 418,144	\$ 357,409
**Additional need for unrestricted revenues and funds met from:				
Use of Facilities Allowances	\$ 1,468	—	\$ 1,468	\$ 1,458
Patent Revenues	1,038	—	1,038	756
Current gifts, grants, and bequests	3,662	—	3,662	3,407
Total additional current revenues	6,168	—	6,168	5,621
Less: funds available for future operations	376	—	376	56
Net additional current revenues used	5,792	—	5,792	5,565
Other fund balances	—	—	—	—
Funds functioning as endowment	—	—	—	—
Total	\$ 5,792	—	\$ 5,792	\$ 5,565

The accompanying notes are an integral part of the financial statements.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
INVESTMENT INCOME FOR DISTRIBUTION TO FUNDS
for the year ended June 30, 1980
with comparative totals for 1979
(in thousands of dollars)

Schedule B

	<i>General Investments</i>	<i>Separately Invested Funds</i>	Total 1980	<i>Total 1979</i>
Investment income before distribution:				
Investment income for distribution to funds, balance beginning of year	\$ 23,578	—	\$ 23,578	\$ 20,710
Investment income, current year	<u>28,789</u>	<u>\$ 2,435</u>	<u>31,224</u>	<u>26,581</u>
Total before distribution	\$ 52,367	\$ 2,435	<u>54,802</u>	<u>47,291</u>
Distribution:				
Income distributed:				
From current year's earnings	\$ (25,824)	(2,435)	(28,259)	(23,713)
From prior years' earnings	<u>—</u>	<u>—</u>	<u>—</u>	<u>—</u>
*Total distribution to funds	(25,824)	(2,435)	(28,259)	(23,713)
 Investment income for distribution to funds, balance end of year	 <u>\$ 26,543</u>	 <u>\$ —</u>	 <u>\$ 26,543</u>	 <u>\$ 23,578</u>
 Balances include:				
Funds functioning as endowment	\$ 15,000	\$ —	\$ 15,000	\$ 15,000
Current invested funds	<u>11,543</u>	<u>—</u>	<u>11,543</u>	<u>8,578</u>
 Total	 <u>\$ 26,543</u>	 <u>\$ —</u>	 <u>\$ 26,543</u>	 <u>\$ 23,578</u>
			(Schedule C)	(Schedule C)
 *Total distribution to funds:				
Endowment funds:				
Used for operations (Schedule A)	\$ 12,317	\$ 34	\$ 12,351	\$ 11,654
Used for scholarships and fellowships	3,385	125	3,510	2,812
Used for other charges	41	12	53	(17)
Added to principal	13	182	195	158
Added to unexpended balances of endowment income	422	12	434	208
Transferred to other funds	<u>4,333</u>	<u>151</u>	<u>4,484</u>	<u>4,584</u>
Total	\$ 20,511	\$ 516	<u>21,027</u>	<u>19,399</u>
 Other funds:				
Agency funds	61	—	61	38
Life income funds	22	814	836	443
Student loan funds	20	—	20	14
Building funds	1,000	313	1,313	1,144
Other expendable funds	<u>4,210</u>	<u>792</u>	<u>5,002</u>	<u>2,675</u>
Other funds	<u>5,313</u>	<u>1,919</u>	<u>7,232</u>	<u>4,314</u>
Total distribution to funds	<u>\$ 25,824</u>	<u>\$ 2,435</u>	<u>\$ 28,259</u>	<u>\$ 23,713</u>

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

BALANCE SHEET

at June 30, 1980

with comparative totals at June 30, 1979

(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 1980	Total 1979
ASSETS								
Cash:								
Unrestricted	\$ (657)	\$ —	\$ —	\$ —	\$ —	\$ —	\$ (657)	\$ 2,243
Other	(1,308)	—	—	1,376	—	—	68	2,641
Accounts receivable	14,224	—	—	—	—	—	14,224	12,675
Students' notes receivable	—	—	29,359	—	—	—	29,359	27,692
Contracts in progress, principally U.S.								
Government	9,514	—	—	—	—	—	9,514	8,759
Deferred charges, inventories and other assets	20,335	—	—	—	—	—	20,335	13,696
Investments, at cost (Note B)	—	61,413	—	310,044	12,442	12,763	396,662	387,209
Receivables (payables) arising from								
investment transactions	—	—	—	739	—	—	739	1,319
Due from other MIT funds	14,575	6,877	—	—	—	—	21,452	20,078
Land, buildings, and equipment, at cost	—	—	—	—	206,700	—	206,700	203,468
Construction in progress	—	—	—	—	23,788	—	23,788	4,727
Temporary investments and cash	—	—	—	—	31,716	—	31,716	—
Total assets	<u>\$56,683</u>	<u>\$68,290</u>	<u>\$29,359</u>	<u>\$312,159</u>	<u>\$274,646</u>	<u>\$12,763</u>	<u>\$753,900</u>	<u>\$684,507</u>
LIABILITIES AND FUND BALANCES								
Liabilities:								
Accounts payable and accruals	\$33,348	\$ —	\$ —	\$ —	\$ —	\$ —	\$ 33,348	\$ 28,683
Withholdings, deposits and other credits	7,755	—	—	—	—	—	7,755	6,491
Advances and unexpended grants for								
sponsored research:								
U.S. Government	(1,495)	—	—	—	—	—	(1,495)	6,264
Private sources	373	—	—	—	—	—	373	374
Due to other MIT funds	—	16,314	14	—	5,124	—	21,452	20,078
Borrowings—Mortgage bonds and								
notes payable (Note E)	1,111	1,739	6,496	396	68,002	—	77,744	39,612
Total liabilities	<u>\$41,092</u>	<u>\$18,053</u>	<u>\$ 6,510</u>	<u>\$ 396</u>	<u>\$73,126</u>	<u>—</u>	<u>\$139,177</u>	<u>\$101,502</u>
Fund Balances:								
Expendable:								
Unrestricted purposes	\$ 376	—	—	—	—	—	\$ 376	124
Restricted gifts and other receipts available								
for current expenses	15,215	—	—	—	—	—	15,215	11,882
Restricted purposes	—	33,482	—	—	—	—	33,482	30,866
Unexpended endowment income for restricted	—	5,212	—	—	—	—	5,212	4,778
purposes	—	5,212	—	—	—	—	5,212	4,778
Investment income for distribution to funds								
(Schedule B — Note C)	—	11,543	—	15,000	—	—	26,543	23,578
Student loan funds (Note D)	—	—	22,849	—	—	—	22,849	21,245
Endowment and similar funds								
Income for unrestricted purposes:								
Endowment	—	—	—	50,372	—	—	50,372	49,341
Funds functioning as endowment	—	—	—	31,004	—	—	31,004	30,311
Income for restricted purposes:								
Endowment	—	—	—	109,330	—	—	109,330	101,036
Funds functioning as endowment	—	—	—	70,812	—	—	70,812	69,634
Net realized gain from investments	—	—	—	35,245	—	—	35,245	34,941
Educational plant funds:								
Unexpended	—	—	—	—	12,306	—	12,306	21,448
Expended	—	—	—	—	189,214	—	189,214	172,444
Funds subject to life interests in income	—	—	—	—	—	11,924	11,924	10,641
Agency funds	—	—	—	—	—	839	839	736
Total fund balances	<u>15,591</u>	<u>50,237</u>	<u>22,849</u>	<u>311,763</u>	<u>201,520</u>	<u>12,763</u>	<u>614,723</u>	<u>583,005</u>
Total liabilities and fund balances	<u>\$56,683</u>	<u>\$68,290</u>	<u>\$29,359</u>	<u>\$312,159</u>	<u>\$274,646</u>	<u>\$12,763</u>	<u>\$753,900</u>	<u>\$684,507</u>

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
CONDENSED STATEMENT OF CHANGES IN FINANCIAL POSITION
for the year ended June 30, 1980
with comparative totals for 1979
(in thousands of dollars)

Schedule D

	<u>Current Funds</u>		<i>Total Current Funds</i>	<i>Endowment, Plant, and Similar Funds</i>	Total 1980	<i>Total 1979</i>
	<i>Unrestricted</i>	<i>Institute or Donor Restricted</i>				
BALANCES, BEGINNING OF YEAR	\$ 124	\$ 56,104	\$ 56,228	\$566,389	\$622,617	\$586,164
Current Year:						
Revenues, other additions, and borrowings	108,862	321,818	430,680	67,172	497,852	403,470
Operating expenses (Schedule A)	(108,310)	(309,834)	(418,144)	—	(418,144)	(357,409)
Other deductions and repayment of borrowings	<u>(76)</u>	<u>(2,224)</u>	<u>(2,300)</u>	<u>(7,558)</u>	(9,858)	<u>(9,608)</u>
Net increase (decrease) before appropriations	476	9,760	10,236	59,614	69,850	36,453
Appropriations among funds	<u>(224)</u>	<u>2,438</u>	<u>2,214</u>	<u>(2,214)</u>	<u>—</u>	<u>—</u>
NET INCREASE (DECREASE) FOR THE YEAR	<u>252</u>	<u>12,198</u>	<u>12,450</u>	<u>57,400</u>	<u>69,850</u>	<u>36,453</u>
BALANCES, END OF YEAR	<u>\$ 376</u>	<u>\$ 68,302</u>	<u>\$ 68,678</u>	<u>\$623,789</u>	<u>\$692,467</u>	<u>\$622,617</u>
BALANCES, END OF YEAR INCLUDE:						
Fund balances	\$ 376	\$ 65,452	\$ 65,828	\$548,895	\$614,723	\$583,005
Outstanding borrowings	—	2,850	2,850	74,894	77,744	39,612
Total	<u>\$ 376</u>	<u>\$ 68,302</u>	<u>\$ 68,678</u>	<u>\$623,789</u>	<u>\$692,467</u>	<u>\$622,617</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, 1980
with comparative totals for 1979
(in thousands of dollars)

Schedule D-1

	<i>Current Funds</i>			<i>Student Loan Funds</i>
	<i>Unrestricted</i>	<i>Institute or Donor Restricted</i>	<i>Total Current Funds</i>	
BALANCES, BEGINNING OF YEAR	<u>\$ 124</u>	<u>\$ 56,104</u>	<u>\$ 56,228</u>	<u>\$ 27,787</u>
REVENUES, OTHER ADDITIONS AND BORROWINGS:				
Tuition and other related income	49,857	—	49,857	—
Research revenues	44,989	251,643	296,632	—
Fees, services and miscellaneous receipts	1,748	12,184	13,932	1,042
Investment income	7,565	21,425	28,990	23
Net realized gain or (loss) on investments	—	5	5	—
Student aid from foundations and agencies	—	10,756	10,756	1,491
Government support for construction	—	—	—	—
Dining and Housing	—	9,321	9,321	—
MIT Press	—	5,092	5,092	—
Gifts, grants and bequests	3,662	10,101	13,763	119
Patent royalties received net of cost	1,041	180	1,221	—
Borrowings	—	1,111	1,111	4,050
Total revenues, other additions and borrowings	<u>108,862</u>	<u>321,818</u>	<u>430,680</u>	<u>6,725</u>
EXPENDITURES, OTHER DEDUCTIONS AND REPAYMENT OF BORROWINGS:				
Operating expenses (Schedule A)	108,310	309,834	418,144	—
Other deductions	76	2,059	2,135	119
Repayment of borrowings	—	165	165	4,096
Total expenditures, other deductions and repayment of borrowings	<u>108,386</u>	<u>312,058</u>	<u>420,444</u>	<u>4,215</u>
Net increase (decrease) before appropriations	<u>476</u>	<u>9,760</u>	<u>10,236</u>	<u>2,510</u>
APPROPRIATIONS AMONG FUNDS:				
Unrestricted funds transferred to funds functioning as				
endowment	(610)	—	(610)	—
Appropriations for buildings added to educational plant	(1,227)	14	(1,213)	—
Expendable funds used to support related expenses	—	3,718	3,718	(1,058)
Other appropriations	1,613	(1,294)	319	106
Total appropriations among funds	<u>(224)</u>	<u>2,438</u>	<u>2,214</u>	<u>(952)</u>
NET INCREASE (DECREASE) FOR THE YEAR	<u>252</u>	<u>12,198</u>	<u>12,450</u>	<u>1,558</u>
BALANCES, END OF YEAR	<u>\$ 376</u>	<u>\$ 68,302</u>	<u>\$ 68,678</u>	<u>\$ 29,345</u>
BALANCES, END OF YEAR INCLUDE:				
Fund balances	\$ 376	\$ 65,452	\$ 65,828	\$ 22,849
Outstanding borrowings	—	2,850	2,850	6,496
Total	<u>\$ 376</u>	<u>\$ 68,302</u>	<u>\$ 68,678</u>	<u>\$ 29,345</u>

<i>Endowment and Similar Funds</i>	<i>Educational Plant</i>		<i>Life Income and Agency Funds</i>	Total 1980	<i>Total 1979</i>
	<i>Unexpended Funds</i>	<i>Used for Educational Plant</i>			
<u>\$302,819</u>	<u>\$ 21,448</u>	<u>\$202,958</u>	<u>\$ 11,377</u>	<u>\$622,617</u>	<u>\$586,164</u>
—	—	—	—	49,857	45,028
—	—	—	—	296,632	249,666
5	225	1,032	145	16,381	11,646
—	1,313	—	898	31,224	26,581
316	—	—	(32)	289	5,369
—	—	—	—	12,247	11,060
—	748	—	—	748	774
—	—	—	—	9,321	8,643
—	—	—	—	5,092	4,613
9,217	6,964	—	1,319	31,382	30,580
5	—	—	—	1,226	904
156	—	38,136	—	43,453	8,606
<u>9,699</u>	<u>9,250</u>	<u>39,168</u>	<u>2,330</u>	<u>497,852</u>	<u>403,470</u>
—	—	—	—	418,144	357,409
—	1,515	—	769	4,538	3,426
412	—	647	—	5,320	6,182
<u>412</u>	<u>1,515</u>	<u>647</u>	<u>769</u>	<u>428,002</u>	<u>367,017</u>
<u>9,287</u>	<u>7,735</u>	<u>38,521</u>	<u>1,561</u>	<u>69,850</u>	<u>36,453</u>
610	—	—	—	—	—
—	(14,524)	15,737	—	—	—
—	(2,660)	—	—	—	—
(557)	307	—	(175)	—	—
53	(16,877)	15,737	(175)	—	—
9,340	(9,142)	54,258	1,386	69,850	36,453
<u>\$312,159</u>	<u>\$ 12,306</u>	<u>\$257,216</u>	<u>\$ 12,763</u>	<u>\$692,467</u>	<u>\$622,617</u>
\$311,763	\$ 12,306	\$189,214	\$ 12,763	\$614,723	\$583,005
396	—	68,002	—	77,744	39,612
<u>\$312,159</u>	<u>\$ 12,306</u>	<u>\$257,216</u>	<u>\$ 12,763</u>	<u>\$692,467</u>	<u>\$622,617</u>

MASSACHUSETTS INSTITUTE OF TECHNOLOGY
SUMMARY OF CHANGES IN INVESTED FUND BALANCES*

for the ten years ended June 30, 1980

(in thousands of dollars)

Schedule E

	1980	1979	1978	1977
Fund balances at beginning of year	\$410,561	\$379,121	\$359,356	\$349,643
Sources of funds:				
Gifts and bequests (Note A)	\$ 31,382	\$ 30,580	\$ 28,236	\$ 23,044
Investment income (Note C)	31,224	26,581	22,441	19,783
Net gain or (loss) on sales or exchanges of investments.	289	5,369	(3,908)	(4,872)
Royalties received net of related costs	1,226	904	828	663
Receipts from foundations and agencies for student aid	10,756	9,960	8,021	4,733
Appropriations from research contract allowances	1,802	1,799	1,768	1,648
Government construction grants	748	774	64	218
Government grant for student loans	1,491	1,100	1,207	1,226
Fees, services and other receipts	14,802	12,634	14,105	9,535
	<u>\$ 93,720</u>	<u>\$ 89,701</u>	<u>\$ 72,762</u>	<u>\$ 55,978</u>
Use of funds:				
Used to meet expenses of current operation:				
Endowment investment income (Note C)	\$ 12,351	\$ 11,654	\$ 11,261	\$ 10,873
Gifts, investment income and other receipts	34,235	29,415	24,975	21,293
Scholarship and fellowship awards for tuition and stipends	13,872	11,962	10,615	9,580
Additions to educational plant	15,737	1,919	1,307	1,179
Operating expenses recorded in direct expenses of the Office of Sponsored Programs	152	474	230	399
Other charges to funds not related to current operation	2,425	2,837	4,609	2,941
	<u>78,772</u>	<u>58,261</u>	<u>52,997</u>	<u>46,265</u>
Net increase in funds	<u>14,948</u>	<u>31,440</u>	<u>19,765</u>	<u>9,713</u>
Fund balances at end of year	425,509	410,561	379,121	359,356
Less gifts and other receipts available for current expenses	15,215	11,883	11,400	11,134
Total invested funds	<u>\$410,294</u>	<u>\$398,678</u>	<u>\$367,721</u>	<u>\$348,222</u>

*This schedule has not been revised to correspond to Schedules A through D-1, however, the data is comparable for the years presented.

<i>1976</i>	<i>1975</i>	<i>1974</i>	<i>1973</i>	<i>1972</i>	<i>1971</i>
\$344,907	\$343,964	\$342,058	\$335,318	\$328,247	\$302,901
\$ 18,528	\$ 16,782	\$ 18,215	\$ 16,919	\$ 17,081	\$ 34,186
18,532	18,332	19,099	18,321	16,942	15,498
(2,610)	443	712	2,429	1,931	7,598
459	455	953	1,310	978	1,058
5,315	5,252	4,321	3,999	4,280	4,787
1,830	1,465	1,426	1,457	1,383	1,209
—	499	3,024	651	776	—
1,173	975	946	816	923	874
<u>9,884</u>	<u>6,636</u>	<u>3,666</u>	<u>3,978</u>	<u>4,137</u>	<u>4,186</u>
\$ 53,111	\$ 50,839	\$ 52,362	\$ 49,880	\$ 48,431	\$ 69,396
10,301	\$ 10,506	\$ 9,681	\$ 9,794	\$ 9,602	\$ 8,435
21,503	18,602	17,357	9,193	9,471	14,529
8,550	8,285	7,711	7,965	8,162	7,999
3,729	5,867	10,129	11,969	9,151	6,513
1,093	673	983	1,640	2,246	2,869
<u>3,199</u>	<u>5,963</u>	<u>4,595</u>	<u>2,579</u>	<u>2,728</u>	<u>3,705</u>
<u>48,375</u>	<u>49,896</u>	<u>50,456</u>	<u>43,140</u>	<u>41,360</u>	<u>44,050</u>
<u>4,736</u>	<u>943</u>	<u>1,906</u>	<u>6,740</u>	<u>7,071</u>	<u>25,346</u>
349,643	344,907	343,964	342,058	335,318	328,247
<u>10,454</u>	<u>10,743</u>	<u>9,660</u>	<u>8,927</u>	<u>7,680</u>	<u>6,893</u>
\$339,189	\$334,164	\$334,304	\$333,131	\$327,638	\$321,354

**MASSACHUSETTS INSTITUTE OF TECHNOLOGY
HIGHLIGHTS: A DECADE IN REVIEW***

(in thousands of dollars)

Schedule F

	1980	<i>1979</i>	<i>1978</i>	<i>1977</i>
Total Operating Expenses	\$418,144	\$357,409	\$319,356	\$276,912
Instruction and Un-sponsored				
Research Expenses	60,892	53,381	47,245	43,311
Direct Costs of Sponsored Research	251,643	209,800	186,331	158,307
Expenses Jointly Applicable to both				
Instruction and Research	69,099	61,907	57,172	50,291
Scholarships and Fellowships	14,267	12,329	11,085	9,843
Research Revenues	\$296,632	\$249,666	\$221,549	\$189,639
Tuition and Other Related Income	49,857	45,028	41,366	37,939
Investment Income	\$ 31,224	\$ 26,581	\$ 22,441	\$ 19,783
Total Gifts, Grants and Bequests	\$ 31,382	\$ 30,580	\$ 28,236	\$ 23,044
For Endowment	9,217	8,354	6,420	7,137
For Buildings	6,964	6,065	8,918	4,855
Total Fund Balances	\$614,723	\$583,005	\$548,976	\$529,010
Endowment and Similar Funds	311,763	302,819	273,881	269,656
Current Funds	65,828	56,228	58,026	52,055
Book Value of Educational Plant	230,488	208,195	205,992	203,340
Investments, at Cost	396,662	387,209	348,481	332,706
Investments, at Market	507,471	467,094	409,528	401,096
Borrowings by MIT	77,744	39,612	37,188	37,688
Undergraduate Students ***	4,478	4,539	4,506	4,422
Graduate Students ***	4,146	3,944	3,824	3,774
Library, printed volumes and microforms (thousands of volumes)	2,745	2,613	2,492	2,376
Tuition Rate (in dollars) ****	\$ 5,300	\$ 4,700	\$ 4,350	\$ 4,000

* Where appropriate the data for the years 1971-1975 have been reclassified for comparison purposes.

** Draper Laboratory divested as of July 1, 1973

*** Full time enrollment

**** Includes mandatory medical fee for 1980

<i>1976</i>	<i>1975</i>	<i>1974**</i>	<i>1973</i>	<i>1972</i>	<i>1971</i>
\$269,250	\$247,441	\$233,442	\$279,061	\$245,127	\$223,222
40,112	37,591	33,711	29,449	26,976	27,918
157,433	142,824	139,980	192,849	161,630	140,386
48,169	45,163	39,747	37,745	37,835	36,751
8,847	8,513	7,912	8,108	8,344	8,074
\$186,637	\$169,757	\$162,372	\$219,447	\$187,715	\$163,429
34,473	29,950	27,004	24,571	22,512	21,548
\$ 18,532	\$ 18,332	\$ 19,099	\$ 18,321	\$ 16,942	\$ 15,498
\$ 18,528	\$ 16,782	\$ 18,215	\$ 16,919	\$ 17,081	\$ 34,186
5,502	3,634	3,904	2,127	2,680	3,863
3,196	4,703	5,553	5,450	2,415	2,514
\$517,458	\$508,329	\$500,925	\$488,240	\$469,050	\$452,558
241,192	239,248	234,551	229,327	221,827	216,364
75,566	76,097	81,476	84,693	85,341	80,505
201,823	197,513	190,029	182,063	157,651	143,120
319,878	313,624	318,321	318,513	312,288	303,287
401,006	376,061	365,631	420,104	425,402	382,539
30,520	30,122	29,369	30,782	20,720	17,408
4,358	4,048	4,018	4,105	4,054	4,058
3,603	3,468	3,358	3,328	3,250	3,296
2,236	2,109	1,995	1,879	1,733	1,566
\$ 3,700	\$ 3,350	\$ 3,100	\$ 2,900	\$ 2,650	\$ 2,500

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, 1980, and 1979, 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 \$206,000 as well as \$4,918,000 of borrowings from current invested funds (at 6% and 8% interest) related to the temporary funding of certain buildings.

B. INVESTMENTS

Total market value of investments approximated \$507,471,000 and \$467,094,000 at June 30, 1980 and 1979, 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. INVESTMENT INCOME FOR DISTRIBUTION TO FUNDS

At June 30, 1980 and 1979, the Institute had accumulated in a reserve \$26,543,000 and \$23,578,000 (captioned "Investment Income for Distribution to Funds") representing fund income in excess of amounts distributed to funds in prior years. These funds were increased by \$2,965,000 in 1980 and by \$2,868,000 in 1979 as a result of the difference between income earned and income distributed to funds (see Schedule B). The total income earned has been reported as revenue in the Statement of Changes in Financial Position. The accumulated amounts are held for distribution to the participating funds in accordance with established methods.

D. STUDENT LOAN FUNDS

National Direct Student Loan Funds of \$14,488,000 and \$13,141,000 at June 30, 1980 and 1979 respectively, are ultimately refundable to the United States Government.

E. BORROWINGS — MORTGAGE BONDS AND NOTES PAYABLE

Borrowings — Mortgage Bonds and Notes Payable consist of the following at June 30, 1980 and 1979:

MIT Construction and Consolidation Bonds of 1968:	1980	1979
Series A, 3 ½ %, due 1980-2003	\$ 4,363,000	\$ 4,493,000
Series B, 3 ¾ %, due 1980-2015	3,521,000	3,566,000
Series C, 3%, due 1980-2018	1,510,000	1,530,000
	<u>\$ 9,394,000</u>	<u>\$ 9,589,000</u>
Dining facilities bonds, 3 ¼ %, due 1980-1999	267,000	276,000
Mortgage notes payable 3%, due 1981-1990	136,000	—
Mortgage notes payable, 5 ¼ %, due 1980-1981	75,000	151,000
Residential facility lease purchase obligation (note F)	4,905,000**	4,993,000**
Mortgage notes payable, 5-6 ½ %, due 1980-2003	9,260,000	9,450,000
Mortgage notes payable, 5-7%, due 1980-2006	5,965,000	6,055,000
Mortgage notes payable 6-8%, due 1982-2011	38,000,000	—
Total related to educational plant	<u>\$68,002,000*</u>	<u>\$30,514,000*</u>
Notes payable 6%, due 1980-1988	1,739,000	1,904,000
Notes payable 13%, due 1980-1982	—	400,000
Notes payable 9 ½ %, due 1980-1989	119,000	128,000
Notes payable 8 ½ %, due 1980-1999	121,000	124,000
Notes payable — due 1980-1985	156,000	—
Total related to investment real estate	<u>2,135,000</u>	<u>2,556,000</u>
Notes payable SLMA, variable %, due 1983		
for student loans	2,000,000	2,000,000
Notes payable to bank, 11 ½ %-15 ¼ % due 1979 for student loans ...	3,850,000	3,750,000
Notes payable to bank, 15 ¼ %, due 1980 for		
Faculty and Staff Educational Loan Fund	200,000	300,000
Notes payable to U.S. Government, 6 ½ %-8 ½ %, due 1980-1992,		
for student loans	446,000	492,000
Mortgage notes payable, 3%, due 1981-2020	1,111,000	—
Total	<u>\$77,744,000</u>	<u>\$39,612,000</u>

*At June 30, 1980 the Institute had pledged securities with a market value of \$57,184,000 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.

F. 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 \$400,000 and are being charged to plant operations as incurred.
2. The Institute is committed under real estate leases to a gross annual payment of \$1,197,000 in 1981. Certain leases expiring in 1980 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 \$692,000 in fiscal 1981. Upon its expiration in 1981, the lease is subject to renewal at a rate of \$143,000 annually.

G. RETIREMENT FUNDS

The Institute's retirement plans, which cover substantially all employees, are under the supervision of trustees. Plan assets are not included in the Institute's financial statements. Current service costs of the plans are funded as incurred. Pension expense charged to operations was \$13,805,000 and \$11,641,000 in fiscal 1980 and 1979 respectively. As of July 1, 1979, an unfunded past service liability of \$4,668,000 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 have received notification of continued qualification from the Internal Revenue Service.

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, 1980 with Comparative Totals for 1979.

Schedule B—Investment Income for Distribution to Funds for the Year Ended June 30, 1980 with Comparative Totals for 1979.

Schedule C—Balance Sheet as of June 30, 1980 with Comparative Totals for 1979.

Schedule D—Condensed Statement of Changes in Financial Position for the Year Ended June 30, 1980 with Comparative Totals for 1979.

Schedule D-1—Statement of Changes in Financial Position for the Year Ended June 30, 1980 with Comparative Totals for 1979.

Schedule E—Summary of Changes in Invested Fund Balances for the Ten Years Ended June 30, 1980.

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, 1979.

In our opinion, the financial statements referred to above present fairly the financial position of Massachusetts Institute of Technology at June 30, 1980, 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, 1980 in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

Coopers & Lybrand

Boston, Massachusetts, September 8, 1980

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.

Auxiliary Activities — refers to the operations of Dining and Housing and MIT Press.

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 MIT *Report of the Treasurer*.

“MIT, 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 MIT 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 and Secretary of the Corporation

The Secretary of the Corporation serves as the Corporation's annually elected Recording Officer and joint signatory with the President in the awarding of the academic degrees of the Institute. The Officers and Committees of the Corporation rely upon the Secretary of the Institute to provide a range of support for the operation of the Corporation and its Committees. This report summarizes the work of the Institute's governing body.

Corporation Membership

At the year's end, the record total of 99 Members of the Corporation included 77 Active Members, 21 Life Members Emeriti, and one Member-Elect due to assume office at the September 26, 1980 Annual Meeting of the Corporation. There were 20 individuals whose membership status changed during 1979-80 in a busy year for the Membership Committee.

At the October 5, 1979 Annual Meeting of the Corporation, Chancellor Paul E. Gray was elected fourteenth President of the Institute to succeed President Jerome B. Wiesner, effective July 1, 1980. The announcement of his election by Chairman Howard W. Johnson, to an overflow special meeting of the faculty convened by President Wiesner in Huntington Hall, Room 10-250, was greeted with a prolonged standing ovation at noon on October 5.

At the special meeting of the faculty, Dr. Johnson expressed appreciation to the Corporation Committee on the Presidency, under the chairmanship of Carl M. Mueller; the Corporation Joint Advisory Committee on Institute-Wide Affairs, under the chairmanship of Gregory Smith; and the Faculty Advisory Committee, under the chairmanship of Professor John Waugh of the Department of Chemistry. All of these committees, as well as the MIT Alumni Association and other groups at MIT, played important advisory roles in the selection of Dr. Gray as President Wiesner's successor.

At the Annual Meeting of the Corporation, John J. Wilson, Class of 1929, concluded 20 years of dedicated service as Secretary and was elected Honorary Secretary of the Corporation in recognition of his long tenure as an Officer of the Corporation. During Mr. Wilson's service as Secretary, he continued the MIT tradition of hand signing all diplomas, using the same pen as his predecessor for the individual signing of nearly 45,000 MIT degrees. This marathon accomplishment represents almost half of the MIT degrees awarded since the founding of the Institute and more degrees signed than by any other official in the Institute's history. Mr. Wilson was succeeded as Secretary of the Corporation by Vincent A. Fulmer, Class of 1953, longtime Secretary of the Institute, at the Annual Meeting.

At its June 2, 1980 Meeting, the Corporation set a precedent by electing to Life Membership the retiring President Wiesner, under a new provision of the Bylaws which exempts former Presidents from the exclusion of faculty, staff, and students serving on the Corporation. Also elected to Life Membership at the June Meeting was D. Reid Weedon, Jr., who has served three previous five-year terms.

At its June 1980 Meeting, the Corporation further elected the following Members to five-year terms, effective July 1, 1980: Claude W. Brenner, Class of 1947, Consultant and Corporate Director; Colby H. Chandler, Class of 1963, President, Eastman Kodak Company; Kenneth J. Germeshausen, Class of 1931, Director and Consultant, EG&G, Inc.; Shirley A. Jackson, Class of 1968, Member, Technical Staff, Bell Telephone Laboratories, Inc.; Norman B. Leventhal, Class of 1938, President, The Beacon Companies; Harold J. Muckley, Class of 1939, Consultant; John S. Reed, Class of 1961, Senior Executive Vice President, Citicorp; Jean Riboud, Chairman of the Board, President and Chief Executive Officer, Schlumberger Ltd.; and William J. Weisz,

Class of 1948, Vice Chairman and Chief Operating Officer, Motorola Inc. David R. Wilson, Class of 1973, Senior Engineer, Advanced Materials Technology, Inc., who served an earlier, partial term on the Corporation, was elected a Member at the same Meeting to a five-year term, effective September 26, 1980.

In addition, Harl P. Aldrich, Jr., Class of 1947, Founder and President, Haley & Aldrich, Inc., assumed an ex-officio position on the Corporation by virtue of his election as the 1980-81 President of the Alumni Association. In that position, he succeeded Claude W. Brenner, effective July 1, 1980.

Our Life Member, Russell DeYoung, Class of 1940, former Chairman of the Board, The Goodyear Tire & Rubber Company, transferred to Emeritus status during the year. Mr. DeYoung continues as a member of the Athletics Visiting Committee. He has served with distinction as a Member of the Corporation since 1959 and as a Life Member since 1964.

On March 6, 1980, the Corporation held a reception and dinner at the MIT Faculty Club in honor of President and Mrs. Wiesner, on the occasion of the President's forthcoming retirement. A group of MIT students provided chamber music at the reception. Dr. Johnson presided at the dinner and reviewed the Institute's progress during Dr. Wiesner's presidency. Other speakers were Dr. James B. Fisk, Dr. Gray, The Honorable Luis A. Ferré, and Mrs. Karl T. Compton. Dr. Johnson presented an inscribed silver pitcher to Dr. and Mrs. Wiesner as a memento from the Corporation. He also announced the establishment of a permanently endowed Jerome Bert Wiesner Professorship, through a gift of \$1 million by Schlumberger Ltd., in honor of Dr. Wiesner. Dr. James R. Killian, Jr. joined Dr. Wiesner in the unveiling of Dr. Wiesner's official portrait painted by the noted portrait artist, George Augusta, of Essex, Massachusetts. The following Resolution was adopted by the Corporation at its Meeting on June 2, 1980 by acclamation:

Resolved: That the Corporation of the Massachusetts Institute of Technology unanimously acclaim with deep appreciation the superb leadership of Jerome Bert Wiesner as Thirteenth President of the Institute, and records MIT's lasting debt to him, as he concludes his term as President.

His association with MIT began 38 years ago, when he entered as a staff member of the Radiation Laboratory. From the beginning he brought rare qualities of scientific insight, analytical style, and presence which have left their mark on the Institute.

As Professor, Director of the Research Laboratory of Electronics, Head of the Department of Electrical Engineering, Dean of the School of Science, Provost, and President, he has cultivated and helped to fulfill MIT's highest aspirations. By his gift of lucid exposition he has made clear complex problems and policies and conveyed the objects, aims, and spirit of MIT to a wider audience. This quality manifested itself fully in his role as Science Advisor to Presidents Kennedy and Johnson and in his national advocacy of research universities in their relations with government. His catholicity of mind has given him the qualities of a humanist as well as those of an engineer and scientist, those of administrator as well as those of a scholar. His perceptive concern for the individual, especially the individual student and junior colleagues, has prompted warm appreciation as shown by the numerous student and faculty tributes. The establishment of an endowed Professorship named in his honor bears testimony to the regard of his fellows as teacher and scholar.

His administrative career at MIT has been a period marked by innovation in teaching and undergraduate research with more choices open to the student, with a more flexible curriculum, deepened by science and broadened by augmented resources in the health sciences and technology, energy research, arts, and humanities. His administration has been a period when the bonds of our corporate fellowship have been tightened and a shared sense of purpose enhanced. It has been a period of great building, both physically and intellectually, with wider opportunities for women and minorities. The Institute has grown bigger, but more importantly, it has grown better.

In all this, Dr. Wiesner has played a central and inspiring role. So, too, has Mrs. Wiesner, and we honor both as a team which is greater than the sum of the parts. Her zealous contribution to the expansion of professional opportunities for women in science and technology is a matter of record.

In recording these achievements we also honor those qualities of his which no formal curriculum vitae can capture -- his gift for leadership, his dedication to the successful completion of an unprecedented capital campaign, his good judgment, his sensitive, warmly understanding relations with his colleagues, and his demonstration that one man, and his spouse, can indeed make a difference.

Be It Further Resolved, That the Corporation express its very great satisfaction that Jerome Bert Wiesner will continue his association with the Corporation as a Life Member, and that it express the hope and anticipation that he will find the next chapter of his career as Institute Professor also happy and rewarding.

And Be It Further Resolved, That these resolutions be spread upon the permanent records of the Corporation and that a copy be sent to President and Mrs. Wiesner.

Expiration of term membership has cost the Corporation the formal services of Virgilio Barco, Class of 1943, Ambassador to the United States, Republic of Colombia; Vernon E. Jordan, Jr., President, National Urban League, Inc.; Allan J. MacEachen, Class of 1953, Deputy Prime Minister and Minister of Finance, Canada; and Mary Frances Wagley, Class of 1947, Executive Director, Episcopal Social Services, Diocese of Maryland. These retiring Corporation Members continue their association with the Corporation in many ways as members of various alumni, Corporation, and Institute committees.

Under the Bylaws of the Boston Museum of Fine Arts, the President of MIT annually appoints a representative from MIT 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. Several Corporation Members also serve as MFA Trustees. Dr. Johnson completed his service as President of the Museum of Fine Arts, and in an unprecedented action, he was elected to a new position as Chairman of the Overseers of the Museum of Fine Arts.

Corporation Joint Advisory Committee on Institute-Wide Affairs

CJAC devoted virtually the entire year to a study of the Institute's governance and the participation of students in the general Institute-appointed and faculty committees. CJAC met bi-weekly and monthly on this subject during the year. Several meetings were held with officers of the Institute and of the faculty to develop a consensus about the appropriate focus for this study. Student and faculty representatives on CJAC have given a monumental total of hours and evenings to this effort, which is continuing. Their exceptional dedication to the task at hand has been a source of inspiration throughout the year. The writer wishes to acknowledge the leadership of Gregory Smith and the voluntary assistance given to CJAC by Martha L. Bertrand, Senior Associate, Resource Development Office, who served as Secretary of CJAC. Her cheerful helpfulness has greatly lightened the work required to support the Committee.

Dedications and Special Functions

The Corporation continued to carry prime responsibility for dedications of major facilities and many special functions. In the early months of 1980, plans began for the September 26 Inauguration of President Gray under the chairmanship of an Inaugural Committee headed by Professor Kenneth M. Hoffman. Notable ceremonies this year included the dedication on January 11 of the refurbished Ellen Swallow Richards Lobby in Building 4, sponsored by the Association of MIT Alumnae (AMITA); and the dedication on May 1 of "Guennette," a 46-ton granite, contemporary sculpture by Michael Heizer in Killian Court. Dr. Johnson spoke at the installation of the sculpture, which is on long-term loan to the Institute from the Metropolitan Museum of Art in New York. The Department of Electrical Engineering and Computer Science dedicated a room in honor of the late Professor Lan Chu this spring, and the Northeast Section of the American Chemical Society awarded the newly established Henry A. Hill Prize for the first time on March 13. The prize, which memorializes our late Corporation Member, Henry A. Hill, was presented to Dr. Hill's son, Anthony C. Hill, a staff member at WGBH Educational TV station.

At the December 7, 1979 Corporation Luncheon, our Life Member, Louis W. Cabot, Chairman of the Board, Cabot Corporation, and Chairman of the Sloan Commission on the Federal Government

and Higher Education, spoke about the Commissions's forthcoming report. At the March 7, 1980 Corporation Luncheon, our Corporation Member I.M. Pei, Founder and Principal, I.M. Pei & Partners, Inc., spoke about the challenges confronting contemporary architecture and urban planning.

Another happy event, relating to the Department of Chemistry, is worth noting for the record: the April 16, 1979 tenth anniversary dinner to mark the dedication of the Camile Eduoard Dreyfus Chemistry Building and 10 years of research and teaching in the building. President Wiesner was the principal speaker as he and Dean Robert A. Alberty reviewed the accomplishments of the Department over the past decade. Honored guests included several donors to the building.

MIT Leadership Campaign

The fifth and final year of the MIT Leadership Campaign ended on April 22, 1980 with a total of \$250,232,000 reported by Campaign Chairman Howard W. Johnson to the Alumni Advisory Council at a campaign dinner in Morss Hall in the Walker Memorial Building. At the dinner, President Wiesner and Chancellor Gray joined Dr. Johnson in speaking to the alumni leaders and their spouses to express the Institute's gratitude, and to emphasize the need for continued fund raising to meet the Institute's unfinished business. Their reports were repeated in a series of campaign dinners in New York City, Philadelphia, Chicago, Dallas, and San Francisco and a luncheon in Los Angeles during April and early May. Claude W. Brenner, President of the Alumni Association, presided at the Cambridge dinner. Corporation Members hosted and presided at the other functions in their home cities. The Campaign announcement to the Alumni Advisory Council five years earlier had been made with \$43 million, or only 19 percent of the \$225 million Campaign goal in hand. The rise to 111 percent of the Campaign goal on the fifth anniversary of the Campaign had required a prodigious homestretch effort, Dr. Johnson reported.

By the December 1979 Meeting of the Corporation, the \$225 million five-year Campaign goal was already in hand or pledged. By April 22, 1980 another \$25 million had been raised. Thus, the Campaign went into the record books as the third largest amount ever raised by an American university, behind the capital campaign of Yale University and Stanford University, and with one of the largest overruns in US history for major collegiate campaigns.

The pattern of positive responses from individuals, corporations, and foundations in the fifth and final year of the Campaign was a source of very great encouragement to the Campaign Steering Committee, Dr. Johnson reported. In the last year of the Campaign, our Life Member, Robert C. Guinness, and John S. Reed, Senior Executive Vice President, Citicorp, joined Paul F. Hellmuth, J. Kenneth Jamieson, W.B. Murphy, and Edward O. Vetter as Co-Chairmen of the Campaign. Mr. Guinness had special responsibilities for the conduct of the Campaign in the Chicago area and Mr. Reed for the New York area, in addition to their shared national responsibilities for the Campaign as Co-Chairmen.

Corporation Members serving on the Campaign Steering Committee, in addition to Dr. Killian, President Wiesner, Chancellor Gray, and the Campaign Co-Chairmen were: Paul M. Cook, Luis A. Ferré, Cecil H. Green, Breene M. Kerr, Ralph Landau, Carl M. Mueller, Clint W. Murchison, Jr., D. Reid Weedon, Jr., and John J. Wilson. Paul V. Keyser, Class of 1929, continued his service in the Campaign Steering Committee following his completion of Membership in the Corporation in 1977.

The report on behalf of 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 Co-Chairmen, members of the Campaign Steering Committee, Area Chairmen, Corporation Development Committee, and Alumni Fund Board. In addition, many Members of the Corporation have headed or are heading National Sponsoring Committees for particular projects and have made historical gifts on their own. To illustrate, Edward O. Vetter continued to head a national committee to emphasize the importance of endowed professorships to the endowment objective of the Campaign.

Breene M. Kerr completed his role as National Chairman of the Sponsoring Committee for the Building 10 drive to fund the renovation of Huntington Hall, Room 10-250, and to fund the new Alumni Center, and he became Chairman of the MIT Sustaining Fellows. Clint W. Murchison, Jr.

continued as Chairman of the more than \$8.0 million drive for a new Athletics and Special Events Center. The Center is now nearing completion, and will be ready for operation in the fall of 1980. Dr. Gray reported to the Corporation at its June Meeting. Richard L. Terrell continued as Chairman of the National Business Committee seeking major grants from US and foreign corporations. Luis A. Ferré continued as Chairman of the Council for the Arts at MIT, Gregory Smith continued as Chairman of the Arts Council's Development Committee, and the Arts Facilities Sponsoring Committee includes a number of Corporation Members. In Japan, Yaichi Ayukawa continued to serve as a central figure in organizing support by the Japanese government and Japanese companies for the Leadership Campaign. Our former Corporation Member, Paul V. Keyser, received the 1979 Marshall B. Dalton Award of the Corporation Development Committee at its annual meeting "in recognition of conspicuous and sustained service in the enhancing of MIT's financial independence."

President Wiesner's unprecedented withdrawal from the day-to-day management of the Institute during the latter years of the Campaign, in order to work more closely with Chairman Johnson, will stand as one of the major determinants of the success of the Campaign. Closely associated with this, the remarkable ability of Chancellor Gray to carry forward the Institute's momentum on all fronts has been a mainspring in moving the Institute through the Campaign. With his total grasp of the Institute, Chancellor Gray has managed its affairs with consummate skill and grace, and put his own shoulder to the drive, thus contributing in a unique way to the success of the Campaign during its final years.

Altogether, these leadership responsibilities and actions by the Corporation represent a renewed sense of institutional purpose. They constitute an unprecedented demonstration by the Institute's governing body of its commitment to secure the necessary resources for MIT's continued independence and strength. The Institute will always be 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. 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 limitations needed to pull together in planning for a future balanced budget. In addition, through its various committees, the Corporation played a key role in communication with student, faculty, alumni, and the general public on the range of questions and issues before MIT.

Special thanks are due once again to the Ad Hoc Committee on Shareholder Responsibility, under the chairmanship of D. Reid Weedon, Jr., and to CJAC, 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, in a year in which the Institute's investments in South Africa continued to be the focal issue.

Additional thanks are due the Corporation Screening Committee, under the chairmanship of Shirley A. Jackson and the staff of the Alumni Association for the effort required to conduct the special alumni election needed to fill a vacancy in the category of younger Member of the Corporation.

In a notable action, the Corporation voted to approve the consolidation from five to four graduate degree programs to be offered by the Department of Nutrition and Food Science. The Corporation also voted to approve the degree change from S.M. in Shipping and Shipbuilding Management to S.M. in Ocean Systems Management, offered by the Department of Ocean Engineering.

After extended discussions at the quarterly Meetings of the Corporation and in the meetings of the Executive Committee, Council on Resources of the Institute (CRI), Corporation Development Committee (CDC), and the MIT Resource Development staff regarding the terms and conditions of a membership arrangement for non-alumni of the Institute, the MIT Sustaining Fellows was established to help augment and strengthen the network of friends at MIT and to expand the base of the Institute's endowment and unrestricted funds. Our Life Member, Breene M. Kerr, became Chairman of the MIT Sustaining Fellows. President Wiesner and Chairman Johnson became

Honorary Chairmen of the new program, in which many Corporation Members are enrolled in the group of founding members.

The year 1980 marked the conclusion of Dr. Walter A. Rosenblith's participation in the Meetings of the Corporation as Provost of the Institute. His wise counsel will be sorely missed. In looking forward to Provost Francis E. Low's participation in the regular Meetings of the Corporation, the Corporation expresses appreciation to Professor Rosenblith, who has contributed significantly to the discussions in Corporation Meetings during the past nine years.

Corporation Visiting Committees

This was a year of level activity for the Corporation Visiting Committees. Compared with 16 of the 29 Committees which met during the 1978-79 year, 15 meetings were scheduled in 1979-80. One of these meetings involved the Chairmen of the Visiting Committees for the Departments of the School of Engineering. The expansion of the new Visiting Committee for the Whitaker College of Health Sciences, Technology, and Management was continued in 1979-80, with further appointments to be made in 1980-81.

These 15 meetings involved roughly one-half of the total Visiting Committee membership, which now exceeds 550 members with the added appointments to the Whitaker College Visiting Committee. This actual level of Visiting Committee activity was in keeping with a guideline set by the Corporation during 1975-76 to reduce the frequency of meetings for Visiting Committees. The rationale for fewer meetings continued to be sound in the light of the increased outreach activities of the Institute during the intensive period of off-campus campaigning under the capital drive. In addition, in a few cases the turnover among deans and department heads has mitigated the demand for meetings somewhat, as Visiting Committee Chairmen have tried to recognize the need of new department heads for adequate time to develop their plans.

We hope to maintain a level of about 15 or 16 meetings a year, evenly divided between the fall and spring semesters. The calendar for 1980-81 is headed in this direction, with seven of the Visiting Committees already scheduled to meet during the first semester. I want to recognize the dedicated work of the Corporation Visiting Committee Office in the painstaking task of scheduling and staffing these meetings.

Several features of the meetings which have proved successful in the past were continued by the Committees this year. All of the 15 meetings, save the one for the School of Engineering Visiting Committee Chairmen, included 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. One Visiting Committee returned after an interval of only six months to inspect the physical facilities and to recommend a new design facility for the Department of Mechanical Engineering. Discussions with each of the departments had many common interests, including systematic follow-up of previous Committee recommendations and reviews of departmental progress in recruitment of minorities and women as students and faculty members. Several of the departments visited had new department heads, which lent an additional element of importance to those meetings. In one case, Athletics, the Visiting Committee meeting served as an important source of advice to a study of the organization of the Department, and the search for a new Director of Athletics. An interesting visit to the John F. Kennedy Memorial Library at Columbia Point in Boston Harbor was included in the agenda of the Political Science Visiting Committee. Virtually all of the MIT departments visited continued to show budget strains. Those in the School of Engineering reflected the additional acute problems posed by the continued dramatic shift of enrollments toward the School of Engineering.

Attendance by members of the Visiting Committees has been excellent this year. Fifteen 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, considering the Leadership Campaign travel demands on them. The presence of these officers at the various meetings enhances the interchange between the Committee and the Department and often provides a welcome catalytic effect which contributes to the success of the meeting. Enduring thanks are

due Provost Rosenblith for his energetic participation in the meetings and in the selection of new Committee members, and to the more than 300 faculty members who participated in the sessions of the Visiting Committees.

Of the Committees meeting in the 1978-79 year, all of the chairmen have now reported orally to the Corporation, and all 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 MIT. The Academic Council systematically receives copies of the written reports when they are approved for distribution by the Executive Committee, and the Council also hears oral reports from the Provost and the responsible dean or vice president as Visiting Committee meetings occur.

We remain handicapped by reduced staffing of the Visiting Committee operation due to budgetary considerations. A five-year search for volunteer assistance with Visiting Committee arrangements has not been successful, but it continues in order to help fill a staff vacancy. In this interval, the support staff and the writer are sharing the overload.

In conclusion, I wish to thank Dorothy Adler of the MIT Alumni Association for her strong 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 willing assistance and cheerful disposition.

At the close of the year, Jerilyn K. Edmondson completed five years of service and transferred, in order to accept a promotion in the office of Provost Emeritus and Institute Professor Walter A. Rosenblith. She had earlier served for six years in the Office of the Provost prior to joining the Office of the Secretary of the Institute in 1975. She will be sorely missed. The writer wishes to express appreciation to her on behalf of the Corporation.

VINCENT A. FULMER

Alumni Association

The year 1979-80 may best be characterized as a year of change, growth, and achievement. The Alumni Fund exceeded all previous records and its goals by significant amounts. Student programs and student involvement in alumni activities continued to increase dramatically. Paid subscriptions by outside subscribers to *Technology Review* grew from 30,000 to 35,000. At the same time, on-going programs maintained their vitality as alumni volunteers demonstrated a high level of commitment to their programs and to the Institute. Special praise goes to Claude W. Brenner, Class of 1947, President of the Alumni Association, who spent nearly full time in supporting the staff and providing creative guidance.

During the past year, nine members of the staff resigned, ten new staff members were hired and, at year end, there were still two unfilled openings. Dr. James A. Hester, Jr., Class of 1965, who joined the Association in December of 1978, tendered his resignation to the Board of Directors at their meeting on April 10, 1980, and left the Association in June 1980 to accept the position of Associate Director at New England Medical Center Hospital. A search committee, chaired by President Claude W. Brenner, conducted an extensive screening and interviewing process in time to announce in late June the appointment of William J. Hecht, Class of 1961, as the Executive Vice President commencing August 1, 1980. Mr. Hecht is no stranger to MIT or to alumni, having served as Associate Director of Admissions and Director of the Educational Council from 1967 to 1976. Dr. Stephen P. Denker, Class of 1959, resigned as Director of the Alumni Fund in the summer of 1979 to return to industry and Ronald S. Stone, Class of 1959, who had just been appointed Director of Operations on July 1, took over as Interim Director. After an extensive search by a committee chaired by Thomas H. Farquhar, Class of 1960, Joseph S. Collins was promoted from Regional Director for the Midwest to Director of the Alumni Fund in December. Although other changes are mentioned specifically in the appropriate subsections of this report, it is worth noting that during the past year changes took place in all Regional Director positions.

To a large degree the achievements of the past year are attributable to the leadership and continuity provided by the volunteer organization. The Board of Directors, chaired by President Brenner; the Alumni Fund Board, chaired by Christian J. Matthew, Class of 1943; the Alumni Activities Board, chaired by Gordon W. Moore, Class of 1960; and the Alumni Resources Committee, chaired by Dr. Charles E. Kolb, Jr., Class of 1967 deserve special recognition. But it also was the nearly 5,000 alumni volunteers and the many involved students that made this year a success.

During the year, the Board of Directors, recognizing that the five-year Leadership Campaign would end in April 1980 and that on July 1, 1980 Dr. Paul E. Gray, Class of 1954, would be assuming the Presidency, felt that it was appropriate to establish a blue-ribbon long-range planning commission to identify and review the critical issues facing the Institute and the Association as they relate to the basic charter of the Association. At the meeting of the Board of Directors on December 14, 1979, it was voted to direct the President and the Executive Committee to establish such a commission. Subsequently, D. Reid Weedon, Jr., Class of 1941, Life Member of the Corporation and former President of the Alumni Association during 1961-62, accepted the chair of the Long-Range Planning Commission and set as his goal a report with recommendations to be completed by June 30, 1981.

ALUMNI RELATIONS

Over the past few years, the alumni relations staff has focused its creative effort on developing closer ties with students and alumni, on developing means of strengthening the role of volunteers in both the leadership and in the management of programs, and on developing opportunities for

alumni to maintain a continuing intellectual tie to MIT -- primarily through professional relationships with the faculty on a school or departmental basis. At the same time, they have attempted to maintain the same level of support for ongoing class activities, major events, and the various selection and recognition processes. Another important, but less visible, activity involves responding to the various inquiries from alumni, students, and the faculty and staff of the Institute. The new location in Building 10 has done much to increase these communications and has played a major role in enhancing certain programs, primarily those which are student-oriented.

The Alumni Activities Board, chaired by Gordon W. Moore, Class of 1960, determined to study cost-effective ways for alumni relations activities to grow, and to look into income-generating services, such as study-travel and group life insurance programs, to help offset costs. Since the Summer College program has not proved cost effective after three years' experience, the Activities Board recommended, and the Board of Directors approved, discontinuing this activity in its present form and delaying consideration of additional programs until they had an opportunity to study the entire issue of further education, and recommend programs consistent with longer-range plans. The Activities Board established five subcommittees to help formulate these plans as follows: Program Growth and Self-Sufficiency, Leadership Development, Special Interest Groups, Student Programs, and International Programs. During the past year these subcommittees have been conducting surveys, meeting face-to-face and by telephone conferencing, with the objective of presenting a report with recommendations to the Board of Directors at the December 1980 meeting.

The Alumni Activities Board recommended, and the Board of Directors approved, the concept of a Black Alumni of MIT (BAMIT), operating as a special interest organization within the framework and with the support of the Association, and approved modest financial support during the first year of formation. Kenneth J. Armstead, Class of 1975, was elected President at a full-day meeting on Saturday, May 17, 1980, which was attended by representatives from around the country. The officers, in conjunction with local groups, are finalizing their constitution and by-laws and developing specific goals and objectives for the next few years.

Chaired by Dr. Charles E. Kolb, Jr., Class of 1967, the Committee to Strengthen Alumni Involvement with the Institute changed its name to the Alumni Resource Committee (ARC) and altered its focus to concentrate primarily on Course and School programs, with the objective of initiating and executing projects at the request of a department head or projects suggested by the committee with the approval of the department head. Dr. Kolb made presentations to the Board of Directors and the Alumni Activities Board as well as to the Science Council and the Engineering Council. Currently the committee is working with a few departments which have expressed an immediate interest in developing specific programs.

The committee also initiated an International Student Program, under the direction of Thomas J. McNamara, Class of 1945, designed to provide orientation to both undergraduate and graduate students prior to their coming to the US for the first time. Letters with lists of entering students were sent to selected alumni in 29 countries requesting that they organize an effort to meet with these students during the summer. The initial response to this mailing has been encouraging, and plans are under way to evaluate it next fall.

The Awards Committee, which is made up exclusively of past recipients of the Bronze Beaver Award, under the Leadership of Clinton H. Springer, Class of 1945, commissioned Beverly Benson Seamans, a well-known sculptress of animals, to design a new Bronze Beaver Award. The new award is truly a work of art and will be presented for the first time to the recipients this year.

The Board approved the following recommendations of the Awards Committee: the Bronze Beaver Award, the highest award given by the Association, to the following alumni for outstanding service: Harold Bugbee, Class of 1920; Philip K. Bates, Class of 1924; J. Robert Ferguson, Jr., Class of 1937; Samuel A. Goldblith, Class of 1940; Robert L. Rorschach, Class of 1943; and Yaichi Ayukawa, Class of 1952.

The Harold E. Lobdell, Class of 1917, Distinguished Service Award, in recognition of valuable service to the Association and the Institute in one activity or, alternatively, service that is substantial and sustained along broad lines, to the following alumni: Charles H. Chatfield, Class of 1914; James A. Howard, Class of 1925; C. Haskell Small, Class of 1930; Warren J. Henderson, Class of 1933; Ward J. Haas, Class of 1943; James O. McDonough, Class of 1943; Donald E. Robison, Class of 1946; Robert C. Cowen, Class of 1949; Otto E. Kirchner, Jr., Class of 1949; Edwin H. Baker, Class of 1956; Allan S. Bufferd, Class of 1959; Gordon W. Moore, Class of 1960; Margaret L. MacVicar, Class of 1965; Pamela Reekes McKirdy, Class of 1971; and H. DuBose Montgomery, Class of 1971.

The George B. Morgan, Class of 1920, Award, in recognition of sustained excellence in all aspects of Educational Council activities, to the following alumni: Francis O. Merchant, Class of 1933; E. Hibbard Summersgill, Class of 1936; Philip H. Dreissagacker, Class of 1937; Arthur J. Power, Class of 1942; Alan L. MacLean, Class of 1944; Arthur Schwartz, Class of 1947; Thomas E. Pawel, Class of 1948; Bernard Edelman, Class of 1953; and David G. Steelman, Class of 1964.

The Presidential Citation, the highest honor that the Alumni Association bestows upon any of its organizations, was awarded to: Boston Seminar Series; MIT Club of Cleveland Symposium; MIT Club of Fairfield County; and the MIT Club of Palm Beach County.

Three outstanding friends of the Institute were awarded Honorary Membership in the Association: Ida M. Green (Mrs. Cecil), Walter L. Milne, and Ross H. Smith.

Under the chairmanship of Ward J. Haas, Class of 1943, the Committee for Nominations to Corporation Visiting Committees developed a more interactive method of conducting their business, and recommended to the Corporation that 27 members whose terms had ended be discontinued, that 42 terms be extended, and that 33 new alumni members be appointed -- bringing the total number of alumni representatives on the 29 Corporation Visiting Committees to 169.

The National Selection Committee, under Norman B. Leventhal, Class of 1938, met on November 29, 1979, to select the Association's Corporation nominees and national officers as follows: for five-year terms on the Corporation -- Kenneth J. Germeshausen, Class of 1931; Claude W. Brenner, Class of 1947; and John S. Reed, Class of 1961; for a one-year term as Association President -- Harl P. Aldrich, Jr., Class of 1947; for two-year terms as Vice Presidents of the Association -- Mary Frances Wagley, Class of 1947 and Jack C. Page, Class of 1948; for two-year terms as Directors of the Association -- E. Kirkbride Miller, Jr., Class of 1941; Robert W. Mann, Class of 1950; Thomas H. Farquhar, Class of 1960; and Shirley A. Jackson, Class of 1968.

The balloting for alumni to serve on the National Selection Committee was altered this past year as a cost reduction effort. In the past, a ballot had been sent separately to over 50,000 alumni. This year, the ballot was included in an issue of *MIT 1980*, which went to about 60,000 alumni; a dramatic drop in participation was noted. The ballot contained the names of three alumni nominated by clubs in each of the three electoral districts to serve three-year terms on the National Selection Committee. John J. Casey, Class of 1940, Carrollton, TX; Edward D. Kane, Class of 1947, West Hartford, CT; and H. DuBose Montgomery, Class of 1971, Hillsborough, CA were elected.

The Association also supports the Corporation Selection Committee chaired by Shirley A. Jackson, which manages the process for electing one member each year from the three most recent classes -- 1978, 1979, 1980 -- to serve a five-year term on the Corporation. David R. Wilson, S.B. 1973, S.M. 1975, Ph.D. 1980, was selected from a slate of 10 candidates.

The Board of Directors appointed 42 alumni to serve on eight National Boards and Committees and eight alumni to chair these organizations.

Other Committees of a more traditional nature also experienced success this year. The 1980 Technology Day Committee, chaired by Pamela G. Reekes McKirdy, Class of 1971, attracted 13 quinquennial classes from the fifth to the 65th reunions. The program was designed to honor President Jerome B. Wiesner for his nine years as the 13th President of MIT. An encomium in the form of a bound volume containing letters of appreciation from 215 alumni, was presented to him at the awards luncheon and ended with a well-attended reception for him at Walker Memorial. The 1979 Alumni Officers Conference Committee, chaired by Dr. John Blair, Class of 1954, attracted 597 alumni back to campus on September 28 and 29. There, Allan J. MacEachen, Deputy Leader of the Opposition and Opposition House Leader in the Canadian House of Commons, Class of 1953, delivered the Third Annual Robert H. Richards Alumni Lecture to a full house in Room 10-250.

The Alumni Host Family Committee, chaired by Paul Draper, Class of 1971, placed 125 freshmen with an equal number of host families. The Alumni Council Program and Membership Committee, chaired by Charles Hieken, Class of 1951, put together six successful programs. The highlight was a banquet on April 22, 1980, in Walker Memorial at which the final results of the five-year Leadership Campaign, totaling \$250,232,000, were announced, just five years to the day after the Campaign was announced to the Council on April 22, 1975. Approximately 475 alumni and

guests attended this affair. The Association of MIT Alumnae (AMITA), with Susan B. Kannenberg, Class of 1961, as President, held six meetings, including an evening meeting with students and astronaut Dr. Sally K. Ride. The continuing IAP series was well attended and consisted of four informal meetings conducted by Christina H. Jansen, Class of 1963, and Lita L. Nelson, Class of 1964, entitled "Getting the Job you Want in Industry: A Woman's Guerilla Guide to the Pinstriped World."

Mention also should be made of two highly successful locally based alumni efforts which have been self-supporting from their start four years ago and which attained record levels of growth this year as follows: The Boston Seminar Series, a discussion group centered on a theme, conceived by Max Seltzer, Class of 1917, and chaired this year by Donald L. Gillespie, Class of 1949, was oversubscribed and was closed to subscriptions at 100; and the Enterprise Forum, chaired by Dr. Arthur C. Parthe, Class of 1966, an organization that provides an opportunity for small technically oriented businesses and entrepreneurs to present their plans for critiquing to a well-informed panel and audience, grew to a supporting membership of about 200.

Student programs, which saw another year of phenomenal growth, merit special recognition outside the context of the more organized volunteer efforts, because although some of the programs have developed from within the Association's committee structure, many have not. The Student Program Subcommittee of the Alumni Activities Board is looking into a form of overseeing structure that would provide for greater continuity and would improve the coordination of these programs. The Board of Directors, at its December 14th meeting, requested that the Undergraduate Association and the Graduate Student Council appoint student representatives to the standing boards and committees of the Association as well as to other ad hoc committees.

The growth in student interest is clearly the result of the success of past programs and the increased visibility which these have brought about. It is also the result of the fact that other administrative offices of the Institute have perceived the value of alumni as resources and the Association's acting as the catalyst to bring about needed programs. In particular, the Office of the Dean for Student Affairs, the Office of the Advisor to International Students, the Undergraduate Academic Support Office, and the Office for Career Planning and Placement have been supportive of these efforts. Many student groups also have come to see the Association and the alumni as resources; in particular, the Undergraduate Association, the Graduate Student Council, the Interfraternity Council, and the undergraduate class organizations. Programs directly involved 1,950 students and 378 alumni and were well publicized by *Tech Talk* and *The Tech*. A few new programs deserve special mention: the Summer Job Program for freshmen in the Boston area identified 46 companies with openings to which 230 students applied; the Pre-Orientation Program for International Students; a "Survival Seminar" for seniors on such subjects as signing a lease, buying a house, or selecting an insurance program; a Fall Homecoming in conjunction with living groups and athletic events; and a letter to local alumni requesting housing assistance for graduate students, particularly international students. Programs which attracted the largest numbers of student participants were the Fund Telethons, the Alumni Host Family Program, Senior Dinners, various programs conducted during the Independent Activities Period in January, Trailblazing (a career-oriented day of workshops), the Alumni Interfraternity workshops, and the Freshman Summer Jobs Program.

This area of growth, which a few years ago was practically non-existent, continues to have a very high priority and holds out the greatest hope for continued and increased lifelong ties to MIT.

Student programs may also serve as a catalyst in strengthening our international ties. Currently, the Association is able to provide only nominal support to the 10 percent of alumni who live outside the US. This is clearly a growing constituency since about 20 percent of our current student body, primarily graduate students, are international. Although we provide only nominal support, we are observing some growth: Hong Kong has reactivated their club; Italy has started a club; the MIT Club of Colombia has started a branch organization in Cali; and alumni in Greece are expressing interest in organizing. Some US alumni who travel internationally are communicating with these alumni. The Educational Council is expanding its international network of Educational Counselors, and the Alumni Activities Board as well as the Long-Range Planning Commission will be studying this area.

The five members of the alumni relations staff were reduced by one when Nancy J. Wheatley, Class of 1971, accepted a position as a research associate at the MIT Energy Laboratory. Ann V. Welles, Assistant Director Class/Course Programs, offered her resignation effective August 1, 1980, to accompany her husband to the Tuck School at Dartmouth College.

Alumni Association

The following statistical summary of events provides a guide to recent trends in many of the areas of alumni involvement:

<u>EVENT</u>	<u>1979-80</u>	<u>1978-79</u>	<u>1977-78</u>	<u>1976-77</u>	<u>1975-76</u>
Technology Day and Reunions	2,144	2,578	2,361	2,801	2,344
Alumni Officers Conference	597	580	652	571	590
Alumni Council	1,036	906	838	492	806
Club Programs	15,614	16,288*	15,816	13,500	10,765
Conferences and Seminars	580	700	770	900	1,359
Summer College	0	182	50	212	0
Student Programs	<u>2,328</u>	<u>1,288</u>	<u>580</u>	<u>0</u>	<u>0</u>
TOTAL	22,299	22,522*	21,067	18,476	15,864

*Revised figure

REGIONAL ACTIVITIES

The year 1979-80 was one of staff reorganization and personnel changes, which had a major impact on the regional organization. Effective July 1, 1979, Ronald S. Stone, Class of 1959, and formerly Regional Director for the West, was promoted to the newly created position of Director of Operations. Mr. Stone's new responsibilities include coordinating the activities of the Regional Directors and staff as well as those of the New York Alumni Center. During the summer, Robert D. Blake, who had served as New England Regional Director, was reassigned to the Western Region, and Paul E. Johnson rejoined the Institute staff to become the New England Regional Director. Joan G. Sclar, formerly a member of the Alumni Fund support staff, was promoted in August to replace Martha S. Draper, who had resigned earlier as Regional Director for the Southeast. Ms. Sclar, learning later in the fall that she was expecting a child, resigned effective December 31. Her years of service to MIT and most recently to the Alumni Association are valued ones. Also in December, Joseph S. Collins, Regional Director for the Midwest, was promoted to Director of the Alumni Fund, creating a vacancy in that region. On January 1, we were joined by Carol D. Seligson, Class of 1971, and Lawrence E. Milan, formerly of the MIT Office of Personnel, to serve as Regional Directors in the Southeast and Midwest, respectively. Perhaps it is needless to say that a great deal of staff effort was expended this year in becoming acquainted with new geographical areas of responsibility and alumni volunteers, as well as learning and transferring the skills and techniques of volunteer recruitment and management.

Despite this turnover, the staff, working with volunteers nationally, helped to achieve the record Alumni Fund results reported elsewhere by staffing and coordinating in the field the Personal Solicitation and geographical telethon programs. Work with the 50 alumni clubs across the country continued undiminished and with most satisfying results. While the alumni attendance at club meetings decreased slightly, the number of alumni gatherings and the variety of programs which the alumni organized remained at record-high levels. An entrepreneur workshop run jointly with the Harvard Business School; a "chase" of the Tall Ships in Boston Harbor during Operation Sail, which attracted 1,600 alumni and guests on five large excursion craft; and the Cleveland conference entitled "Technology: A Future Necessity?" which was attended by 300 and was both organized and presented almost entirely by local alumni, are but three examples of the breadth of these club efforts. The clubs reach out to alumni -- men and women, young and older; to students -- present and potential -- and are really the hub of local alumni activities. A highlight of

most club calendars is a visit by a member of the MIT community -- faculty or administration. We are grateful to all who have participated, but must single out for special recognition four who made outstanding contributions by visiting and participating in five club functions this year. They are: President Wiesner; Institute Professor Emeritus Harold E. Edgerton; Professor Norman C. Rasmussen, Head, Department of Nuclear Engineering; and Professor Woodie C. Flowers, Department of Mechanical Engineering.

ALUMNI FUND

The phrase "total success" can be used to summarize the results of the 1979-80 Alumni Fund. A record amount of \$6,318,000 was received in gifts to MIT from 23,600 alumni, the largest number of contributors to the Fund in its 39-year history. The gift total represents an increase of 22 percent over the 1978-79 results, while the number of contributors to the Fund increased by 9 percent. Dedicated and hard-working alumni and student volunteers, more than 1,500 of them, made a record number of telephone calls, encouraging alumni to participate in the annual fund and to upgrade their support of MIT. Several programs, including the Personal Solicitation and Telethon efforts initiated during the 1978-79 fund year, were expanded. Furthermore, the staff, aided by improved computer support and at the behest of and in concert with the Alumni Fund Board, increased its efforts to develop meaningful goals and objectives, suitable measurements of success, and detailed program analysis.

The Personal Solicitation (PS) Program was implemented in eight cities during the fall. The cornerstones of this program are extensive prospect screening and solicitor training. Over 160 solicitors made personal visits with some 550 prospects - 75 percent of the alumni made gifts. Consistent with the PS objective of gift upgrading, 71 percent of the alumni who participated made a gift of \$100 or more.

The Young Alumni Program, which began in 1977-78, continued its emphasis on increasing the participation of recent graduates in the Alumni Fund. With the help of the Telethon of the Decade, in which local alumni from the Classes of 1970-79 came to MIT to call classmates who had never given to the fund, and the Associate Agents Program, which involved 34 solicitors from the five youngest classes, the young alumni first-time contributors numbered 670 -- the largest number of first-time gifts from this alumni group in the last decade.

A Senior Pledge Program was initiated this year, asking seniors to make a four-year commitment to the Alumni Fund. A total of \$10,400 was pledged by 150 seniors. The Class of 1980 also continued the tradition of a Senior Class Gift, which was reinstated three years ago. Class members contributed \$1,750, which was matched by the Class of 1930's special challenge. An additional \$4,000 toward the gift was raised by the seniors through the sale of 'Beaver Shirts.' The Senior Gift funds are to be used to purchase electronic scoreboards for duPont Gymnasium and the Alumni Pool.

This year the Fund expanded the Student Telethon Program. More than 400 students participated in this effort, which resulted in 5,000 pledges and \$112,000. The Student Telethon was organized by living group, and callers were recruited by a team of student volunteers. The Telethon provided an opportunity for students to talk with some 8,400 alumni about MIT today. Student callers spoke enthusiastically, emphasizing the need for alumni support of MIT.

In addition to the Student Telethon, three other alumni telethons were held in Cambridge. The first, the Fall Upgrading Telethon, was held in November and the emphasis was on encouraging alumni to increase their level of support to MIT. As mentioned above, in January, the Telethon of the Decade was held, focusing on securing first-time gifts from the members of the 10 most recent classes. The LYBUNT (Last Year But Not This) Telethon, run in May, served as a reminder to alumni who had not yet sent in their contribution to MIT.

In April, a series of geographic telethons was held in 14 cities across the country. This effort involved almost 200 callers who were able to secure 2,259 pledges and \$78,168. One other telethon effort, run as a pilot program, was aimed at increasing participation by those alumni who hold exclusively a graduate degree from MIT. Three academic departments recruited callers from among faculty and other local alumni, and they, in turn, called "department-mates" who had never given to the Fund.

The 25th, 40th, and 50th Reunion Classes of 1955, 1940, and 1930 reported five-year reunion gifts of \$620,000, \$550,000, and \$781,311, respectively. In addition, plans for future gifts from 20 members of the Class of 1930 totaled \$947,000. During the past year, expansion of the Reunion Gift Program has continued. Nine luncheon meetings for alumni approaching 40th, 50th, and post-50th reunions were held in various cities throughout the country. The purpose of the meetings was to inform alumni about the Life Income Plans available at MIT and to make them aware of ways of making a substantial gift at the time of a major reunion. In addition, four classes have undertaken the funding of full and career development professorships as reunion gift projects.

In addition to the Fund's personnel changes mentioned at the beginning of this report, Brenda L. Hambleton, Class of 1979, joined the staff in August as Coordinator of Special Programs, with responsibility for the Telethon and Senior Gift Programs. Also, after 13 years of dedicated service, Jacquelyn M. Findlay, Class of 1944, left the Fund staff to join the Institute's Office of Resource Development.

In summary, by any test one can apply, the 1979-80 Fund year, under the chairmanship of Christian J. Matthew, Class of 1943, was outstanding.

TECHNOLOGY REVIEW

The *Review* reached a landmark in its effort to be at once an effective alumni magazine and a successful "paid"-circulation magazine in 1979-80: our "paid" circulation grew to 35,000 and so equaled alumni circulation. Income from advertising and "paid" subscribers was larger than ever before, making possible substantial improvement in the issues of Volume 82. Covers, and at least one signature of the magazine, were printed in four colors, non-alumni magazines contained (with one exception) 88 pages, and our coverage of MIT affairs for alumni was substantially expanded.

Volume 82 contained a wide range of articles falling within the general scope of new developments in technology and their implications for human affairs. We continued a major focus on energy issues, including energy policy. Cost/benefit analyses applied to technology turned out to be a most controversial subject, and we also generated considerable controversy with articles on the health effects of technologies and their products.

A new format -- panel discussions convened by *Technology Review* for the purpose of presenting divergent views on controversial topics -- proved successful in the hands of Dr. Steven C. Marcus, Managing Editor. The results included a dialogue on the situation of nuclear power technologies after the Three Mile Island accident, and a panel on public perceptions of science and technology based on a session held during the 1980 annual meeting of the American Association for the Advancement of Science in San Francisco.

The skills of Nancy Pokross, Design Director, and Kathleen B. Sayre, Production and Design Manager, resulted in a large number of awards for the magazine's design and illustration during the year.

Inflation and necessary editorial improvements took their toll on the budget in 1979-80, and as the year ended Peter Gellatly and Evelyn Milardo, Business and Circulation managers, respectively, presented a preliminary version of a plan for a major investment in circulation promotion to increase substantially *Technology Review's* paid circulation and increase its income. The *Review's* Advisory Board, reinstated to hear this and other reports of *Technology Review* activities near the end of the year, will review the plan in detail early in 1980-81.

Susanne Fairclough resigned from the Board of Editors during the fall, and Michael D. Feirtag, Class of 1972, resigned at the end of 1979 to join the Board of Editors of *Scientific American*. We were fortunate that Karen Ray could move to *Technology Review* from the News Office to fill one of these places while we conducted a search for permanent successors. As the year ended, Ellen Shell and June Kinoshita, both well-qualified by training and experience in both science and editorial work, became members of the Board of Editors. Meanwhile, Marjorie Lyon rejoined the staff in July 1979 to edit the MIT news section of the *Review*.

ALUMNI RECORDS AND DATA PROCESSING

As of June 30, 1980, the rolls of living alumni included 71,818 names, resulting from the addition of 2,869 names and the removal of 502 alumni reported deceased since the statistics published in the last report.

Starting in July 1979, Association staff and staff from other Institute offices received training in the use of the terminal network to allow direct access to the data on the Alumni records for analysis to support program planning and measurement of program results. Throughout the year, the reports, labels, and other output have been reprogrammed to utilize the new data base system and relieve the load on the old system. Special application files and reports have been developed for the Alumni Officers Conference, Technology Day, and reunions which permit on-line entry and reporting of information related to attendance at these major on-campus events, as well as producing hard copy reports and statistics. In addition, the Business Systems Development team has continued software testing and design development for interactive entry programs. Implementation of the interactive entry system is the next major phase of the project to be accomplished next year. By the start of the following year we will be consolidating the Institute gift system and the Alumni Fund gifts system into a single Gift Master File, and further enhancements to the data base system will be implemented.

RICHARD A. KNIGHT