The MIT Faculty Newsletter

Vol. XV No. 1 **September 2002**

In Memoriam

Lawrence M. Lidsky

On rare occasion a person passes this way whose intelligence and generosity of spirit serve as a beacon to guide others in their chosen task. Such a person was Professor Lawrence Lidsky, and the task was the creation and continuation of the *Faculty Newsletter*.

With a grace uncommon in today's often all-too-impersonal world, Larry devoted extraordinary time and effort not only to his teaching and research, but to the myriad issues and concerns related to our fledgling publication: raising funds, establishing credibility, convincing colleagues to participate. From its inception, Larry served as the *Newsletter's* Faculty Liaison to the administration, and in that capacity was the person most responsible for its eventual legitimization and stabilization. Simply put, without his efforts the *Newsletter* would not have survived.

The passing of a colleague and friend is always difficult for those left behind. Larry Lidsky is greatly missed by all of us who had the good fortune to have known and worked with him.✣

Research at MIT

An Interview with Alice P. Gast

The following interview between the Faculty Newsletter *(FNL) and Vice President for Research and Associate Provost Alice Gast (AG) took place on August 5th of this year.*

FNL: David Litster held your position before you, but the job has been redefined. How do you see it now versus where it was?

AG: Yes, the position has been redefined, and I'm pleased with the redefinition. The title changed from Vice President and Dean of Research to Vice President for Research and Associate Provost. In my view, the importance of the title is that it is to represent working, on one level, as the Vice President for Research, on matters of policy, and another level as an Associate Provost, rather than a Dean. Being an Associate Provost, I can continue to work between school boundaries for the common good of the Institute.

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Editorial

Evolving Research at MIT

Robert A. Brown

This editorial by Provost Bob Brown was written at the request of the Editorial Committee for this issue.

The last few years have seen significant changes in the profile for graduate education and research at MIT. In keeping with MIT tradition, faculty-led research and scholarship maintain their position at the forefront of research, both in the traditional disciplines and in innovative initiatives in emerging fields. Always dynamic throughout the Institute's history, MIT's research portfolio is currently being transformed at an even greater pace.

The beginning of the 2002-2003 school year is a good time to reflect on our present position – what stage are we at in this evolution? At one level the numbers speak for themselves. After a decade of slow or declining research volume, over the last several

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This issue of the *Faculty Newsletter* features research on campus. Beginning on Page 12, the Deans of Engineering, Science, and the Sloan School talk about research at their Schools. From Page 21 onward are other research-oriented articles of importance to the MIT faculty. Next issue we plan to continue this theme and include articles from the Deans of Architecture and Planning and Humanities, Arts, and Social Sciences.

http://web.mit.edu/fnl

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Robert Silbey is Dean of Science.
David Thorburn is Professor of Literature.

From The Faculty Chair

Where Did the Time Go?

Stephen C. Graves

As I write this, I see that the summer is now gone and once again, I have accomplished only a fraction of what I had hoped. There increasingly seems to be too much to do, and not enough time to do it. I wish it were not the case.

Over the past year I have come to appreciate that my dilemma is not atypical among the faculty. A recent quality-of-life survey found that MIT faculty members were working longer hours than a decade ago, and that their level of stress and frustration has also increased. The demands of the job of being a faculty member continue to grow; at the same time, for many of us, the challenge of balancing work and family has become even more difficult.

What might be done to help to alleviate the workload problem? I for sure don't have the answer, and there is no silver bullet. I have found that the administration is sincerely interested in exploring various measures that might help and has taken some positive steps. But it would be useful to them to understand what levers would have the most impact on faculty workload and quality of life. In the remainder of this column, I suggest some possible actions as a way of soliciting your feedback and inputs. My intent is to see if we have the time (?) and energy to engage in a serious discussion about this topic.

There are three main ways that one might affect the workload. We could somehow *increase the time* you can devote to doing your job. We could *increase the efficiency* with which you do your work. We could *reduce the amount of work* you feel compelled to do. To stimulate your thoughts, I'll mention some possible actions within each of these themes.

Increase the Time: Even MIT cannot lengthen the day beyond 24 hours. But there are some possible measures that might allow one to devote more time to the job at MIT.

• Many faculty members spend an inordinate amount of time commuting because they cannot afford housing close to campus. Through a variety of means, MIT might make it easier for faculty to live closer to campus, e.g., MIT-owned apartments with subsidized rents, more generous housing-assistance programs for new faculty, etc.

• For faculty with young children, substantial time is devoted to arranging for and managing their care. MIT has recently expanded the amount of on-campus child-care services. Should MIT do more?

• Some faculty members increasingly work at home for various reasons, e.g., so as to use the odd hours of the day, or to avoid the commute, or to be able to work while managing family responsibilities. Other faculty might like to do so, but would need some assistance from MIT in establishing a home office as well as some infrastructure on campus to support them while working at a distance.

• The Institute could raise faculty salaries, which would permit individual faculty to make their own choices. A faculty member might opt to pay a higher rent or mortgage and live closer to campus, or use the income for a nanny or other child-care services, or invest in a home office, or reduce the number of days consulting.

Increase the Efficiency: We spend a lot of time at our job, but I for one know that I don't always use my time very well. Possibly MIT could help faculty get more accomplished by working more efficiently or effectively.

• We might have more administrative and/or secretarial support, which would permit faculty to leverage their time better by off-loading certain tasks and duties. For instance, suppose you had an administrative assistant who would manage your schedule, handle 80 percent of your e-mail and other correspondence, set up and maintain your Web pages, manage your research accounts, and assist with compiling research reports and proposals?

• We might have more teaching support, such as additional teaching assistants, which might allow us to be more efficient and effective in our teaching. We might use technology better in our teaching, for instance to automate the standard components of our curriculum, allowing more time for individualized instruction.

• MIT might help us acquire better skills for time management and for people management. I am a good example of someone who does not always do a good job of prioritizing tasks and planning my time, or knowing how to say "no." And I expect we could all get more accomplished if we could improve the way we structure and delegate work to our students and staff.

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Where Did the Time Go?

Graves, from preceding page

Reduce the Work: Instead of trying to do more, there might be ways to eliminate or reduce some of what we currently do.

• MIT might increase the number of faculty so as to spread the workload over a larger base. This presumes that we do not expand our educational and research programs with the addition of new faculty.

• The number of graduate students continues to grow, seemingly without much centralized control. There is growth in both research-based graduate programs and professional masters degrees, both of which result in an increased load for faculty. We might collectively decide to cap the number of students, as is done with the undergraduate enrollment, so as to keep ourselves from continuing to pile on more work.

• We might ask for more institutional control on new initiatives that increase the faculty workload. As one example, MIT has launched two major international initiatives (with Singapore and with Cambridge University) that require substantial faculty commitment, often pulling faculty from their responsibilities and teaching duties in their home departments. It is not clear to me that we understood the full impact of these initiatives when they were undertaken. In light of this, we might insist that any proposed initiative be accompanied by an impact statement that documents the faculty load and commitment, and prescribes appropriate recourse or remedies for the departments that are affected.

• We might take greater care in our use and deployment of committees involving faculty. I suspect we have too many standing and ad hoc committees, involving too many faculty members.

• We might seek to develop a better understanding of what is the job of a faculty member, and how this job changes over the course of a career. Possibly there should be a job description that elaborates on what is expected of each of us. This might be quite helpful in individually guiding us in our decisions about what is really important and how best to devote our time.

• Related to the prior point, we could develop metrics on faculty workload. How would you measure what you do, or what you are supposed to do? Presumably, if we could establish meaningful measures on research, on teaching, and on service, we could better manage faculty workload and provide some basis for reducing it.

• Some will say that the workload issues are primarily self-induced, and that this is part of the culture of MIT. If so, then I think the time has come to take a serious look at why this is, and to start the process by which we change the norms, values, and expectations that induce and reward this behavior. This will not be easy.

I started this column with the observation that the faculty has too much to do, and not enough time to do it. I have tried to suggest some possible actions that could help. I am sure there are other ideas. Of course there are cost and resource implications of varying degrees associated with each of these measures. But I believe it would be useful to get a better understanding on which, if any, of these measures would make a difference. I would welcome any input you have on these concerns, as well as on how we might develop an overall sense of what the faculty would want. ✣

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Teaching this fall? You should know …

the faculty regulates examinations and assignments for all subjects.

Check the Web at **http://web.mit.edu/faculty/termregs** for more information on:

- Privacy and student information
- Academic honesty
- Prerequisite subjects for undergraduates
- Grading
- Class times
- The first and third weeks of the term
- Tests and academic exercises outside scheduled class time
- End-of-term assignments
- Final exams and end-of-term tests

Questions? Contact Faculty Chair Stephen Graves at x3-6602 or *exam-termregs@mit.edu*.

TEACH TALK

Efforts to Link Research and Teaching More Closely are Gaining Ground

Lori Breslow

In the university, research and teaching are usually thought of as archenemies whose battlefield is the time and energy of Every Faculty Member. Even those who have attained the Holy Grail of tenure are not immune from the unsettling tug of war the two are forever engaged in.

On the other hand, the common wisdom is that they cannot be uncoupled in the sense that one cannot be a good college teacher without being a strong researcher. Research done to test that belief, however, has proven it not to be true. For example, in 1987, Kenneth Feldman reviewed 43 studies conducted on the relationship between teaching and learning and found ". . . for all practical purposes, [the two] are essentially unrelated." In other words, there was no correlation between research productivity and teaching effectiveness. ("Research Productivity and Scholarly Accomplishment of College Teachers as Related to their Instructional Effectiveness: A Review and Exploration," *Research in Higher Education*, Vol. 26, 1987, p. 275, as quoted in Hattie and Marsh, below.) A similar meta-analysis of 58 studies done nine years later by John Hattie and H.W. Marsh reaffirmed Feldman's findings. "We must conclude," the authors write, "that the common belief that research and teaching are inextricably entwined is an enduring myth." ("The Relationships Between Research and Teaching: A Meta-Analysis," *Review of Educational Research*, Vol. 66, 1996, p. 529.)

(Interestingly, while Hattie and Marsh confirm that prolific research does not correlate with excellent teaching, they did find that those who did both well shared traits in common. "Good researchers and good teachers," they write, "are more enthusiastic, have greater breadth of coverage, are more committed to teaching, and appear more knowledgeable." [p. 529].)

The reality, of course, is that since at least the turn of the century, teaching and research have been in bitter competition, and research has won. In his book, *How Scholars Trumped Teachers,* Stanford education historian Larry Cuban writes, "Amid repeated presidential and faculty claims for the signal importance of teaching and affirmations that harmony, not conflict, characterizes teaching and research, critics and scholars have noted the research imperative as dominating academic work again and again." He ends the paragraph with the cynical, "No news here." (p. 5)

Far be it from me to assert that the playing field between teaching and research is level at MIT. I know of only one faculty member in the Institute who maintains he was tenured because of his contributions to education. And only twice have I been contacted to help young faculty members improve their teaching because there was a fear their tenure cases would be negatively affected by poor student evaluations. So this column is not about how research and teaching happily co-exist at this or any other research institution.

But . . . there are a number of ways the faculty and administration at MIT *have* sought to combine teaching and research so they reinforce one another, and these efforts have born fruit. In this *Teach Talk,* I would like to describe three ways this linking has occurred here: by talking about research in the classroom, through UROP (the Undergraduate Research Opportunities Program), and in subjects that ask students to engage in primary research. Then I would like to briefly detail several endeavors that are going on nationally and internationally to strengthen the connection between teaching and learning.

Efforts at MIT

Intertwining research and teaching can be as simple as a faculty member talking about research (his/hers or someone else's) in class. "When I teach my freshman physics subject (8.022)," explains Professor Peter Fisher, "I make sure to talk about the work that went on at MIT during World War II to develop radar. I think the students should have a sense of how the seemingly abstract concepts they are learning were applied in a way that had profound consequences." And although I've never done a full-scale study on the advantages of talking about research in class, any time the subject has come up in casual conversation with students, they have been nothing less than enthusiastic.

Of course, the most well-known effort to combine teaching and research at MIT is UROP**.** Begun in 1969, UROP was the brainchild of the late Margaret MacVicar, professor of Physical Science and dean for Undergraduate Education, and was "inspired by Edwin H. Land . . . who believed in the power of learning by doing." <http://web.mit.edu/urop/>

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Efforts to Link Research and Teaching Gaining Ground

Breslow, from preceding page

Almost 80% of all MIT undergraduates now participate in at least one UROP during their time at MIT, and UROP has become a model for many programs of its kind at universities throughout the world.

Since I assume most readers of the *Faculty Newsletter* know about UROP, I won't belabor the point except to say that the founding principle behind UROP is that by doing *research* alongside UROP supervisors, those supervisors have the opportunity to *teach* students about the research process, the physical concepts and phenomena underlying the research they are doing, and the knowledge gained as a result of the research program. As UROP Director and Dean for Undergraduate Research Kim Vandiver explains, "UROP allows the students to progress from reading about research and hearing about it to seeing it, doing it, and beginning to understand it." UROP may be the quintessential example of how research and teaching can be interlinked.

UROP connects teaching and research in the lab; other faculty members are making that connection in the classroom. For example, in a new freshman subject called Mission 200X (with "X" standing for the year the students graduate), students work together in their first semester at MIT to solve a complex problem in a novel way. This year, Mission 2006, whose focus will be designing new ways to monitor the status of the Amazon rainforest, will become part of the Terrascope project, which adds a second-semester class in which the students will design and build the computer simulations and experimental observational tools necessary to implement the design they created in the first semester. <http://web.mit.edu/terrascope/www> From the moment they arrive at MIT, these students will be working as researchers, exploring new problems and trying to solve them. But they will do it within the classroom environment.

Aero/Astro Professor David Miller's three-semester course "Space Systems Engineering" (16.83) is another excellent example of how research can be integrated into the classroom. The course is the capstone of the department's undergraduate curriculum, which is based on authentic engineering practice. (The curriculum is known by the acronym CDIO for Conceive, Design, Implement, and Operate.) Professor Miller's course allowed students to work together in teams to develop a concept for a satellite formation flight laboratory for the International Space State, build a high-fidelity prototype, and operate it for short periods of micro-gravity on NASA's KC-135. As Professor Miller and Dr. Doris Brodeur describe the subject in a paper they presented at the 2002 American Society for Engineering Education Annual Conference, it was a win-win situation for everyone. The students received direct experience in the range of work academic and research engineers do, the product made was something of value to the aerospace research community, and "faculty time spent teaching the course would not only meet academic requirements, but also permit faculty members to direct focused activities that supported their research." (p. 3)

These are only a few examples of how research and teaching intersect at MIT; I'm sure many more exist.

Efforts Nationally and Internationally

In 1998, the Carnegie Foundation for the Advancement of Teaching issued the Boyer Commission Report, *Reinventing Undergraduate Education: A Blueprint for America's Research Universities.* <http://naples.cc.sunysb.edu/Pres/boyer.nsf> Charging that "the research universities have too often failed, and continue to fail, their undergraduate populations," the report condemned research universities for not providing undergraduates with opportunities for contact with senior faculty or to do real research. And, in fact, the first recommendation the Commission made for changing undergraduate education was to make research-based learning the standard, with students "engaged in research in as many courses as possible."

The Reinvention Center <http://ws.cc.stonybrook.edu/Reinventioncenter/> was founded at SUNY Stony Brook to promote and coordinate the changes the Boyer Commission advocated. It has established regional networks of research universities to collaborate with one another, and will sponsor a two-day conference in November on "Undergraduate Research and Scholarship and the Mission of the Research University," which representatives from MIT will attend.

Then in August 2001, the Howard Hughes Medical Institute announced it would award $1 million each to 20 research scientists "on the basis of their plans to transmit the excitement and values of scientific research to undergraduate education." Citing the fact that college students are "learning science in the same old way," the Institute hoped to "empower scientists at research universities to . . . 'break the mold' in science education." <http://www.hhmi.org/news>

Two efforts in the UK to connect teaching and research more effectively have also been recently launched. The Linking Teaching and Research in the Disciplines project, centered at Oxford Brookes University, involves producing generic materials to help strengthen the teaching/research links within specific disciplines, as well as creating five Subject Centres that will be discipline specific. <http://www.brookes.ac.uk/> In addition, the Centre for Higher Education Practices at the Open University has undertaken a project entitled, "Maximizing the Benefits to Teaching of Research" in 2001-2002.

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Efforts to Link Research and Teaching Gaining Ground

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There is one more way that prominent scholars have attempted to strengthen the conceptual bond between teaching and research, and that is to undertake what is generally called the "scholarship of teaching." This perspective has been spearheaded by the Carnegie Foundation's CASTL (Carnegie Academy for the Scholarship of Teaching and Learning) Higher Education program. <http://www.carnegiefoundation.org/CASTL/highered/index.htm> This project consists of a fellowship program, underwritten by the Pew National Trust, to bring university faculty together in an advanced study center to explore significant issues in teaching and learning in their fields; the Teaching Academy Campus Program, which is coordinated by AAHE and seeks to create a culture of scholarship in teaching and learning on individual campuses; and interactions with professional and scholarly societies. As Pat Hutchins, who directs CASTL Higher Ed, has exhorted the academic community, it is time for faculty to treat ". . . their classrooms as sites for systematic inquiry; framing their own teaching problems as questions of broader scholarly significance . . . ." (*Ethics of Inquiry: Issues in the Scholarship of Teaching and Learning*, p. 1 at the CASTL Website)

There is no doubt in my mind that pressures – and opportunities – from a number of different quarters are changing the relationship between teaching and learning on the campuses of research universities worldwide. I am glad we are participating in that shift.✣

[Lori Breslow can be reached at lrb@mit.edu]

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Teaching Literature at MIT

David Thorburn

[The following is Professor Thorburn's MacVicar Faculty Fellow acceptance speech, delivered March 1, 2002.]

I feel honored by this award and proud to be part of a university that demonstrates its commitment to undergraduate teaching in such a generous and public way.

My writing and scholarship count a good deal in my sense of who I am, but I've come to realize that my best intellectual energies may emerge in the classroom, in the unpredictableness, the live, existential excitement of the lecture and the seminar.

I've always been offended by those who speak of "the real world" beyond the classroom, as if the passion and seriousness and joy and humility engendered by the work of thinking and learning were "unreal," irrelevant to the practical world. No! no! I want cry out in answer: What could be more real, what could be more useful or valuable than intellectual mastery, true understanding? One reason for this is that truly understanding a problem in biology or chemistry, a historical event or a poem involves a recognition of limitation and complexity, of the partialness of explanations and paradigms, the limits to understanding itself. The humility we learn when we think in these ways is uncommon in our civic and political life, and its relative absence impoverishes us all.

Teaching literature at MIT is a special challenge, and for me an inspiriting one. All of us in the Humanities work in a kind of enclave; some say we work on the margins of the Institute's mission. It is true, of course, that few students choose MIT because they aim to be historians or anthropologists or poets. Yet I feel this makes us not less but more central to the experience of undergraduates. My classes in literature – like the classes of most of my colleagues in the Humanities – have claims on all students, on physicists and engineers, on astronomers, linguists, biologists: on all manner and kind of nerdly genius. Literature – this is a rich paradox – is an amateur discipline: it belongs to all who can read, it addresses the whole human community.

And although it remains one of MIT's best-kept secrets, literature is in actuality a central, shared experience for the vast majority of our undergraduates. 75-80 percent of them take at least one Literature subject before they graduate – a remarkable statistic when we remember that no Literature subject is required. Annual enrollments in Literature have held steady in the 1000-1200 range for the last 25 years, another remarkable fact for a technological institution with fewer than 4500 undergraduates.

I'm deeply grateful for this recognition, but I'm conscious as well of how arbitrary it is for me to be singled out from a group of teachers as gifted and committed as my colleagues in the Literature faculty. They – we – are truly a special group. Better than any faculty I know of in this country, they keep alive the ideal of the teacher-scholar. I accept this award on behalf of my comrades in the Literature Section of MIT: James Buzard, James Cain, Peter Donaldson, Howard Eiland, Mary Fuller, Diana Henderson, John Hildebidle, Noel Jackson, Henry Jenkins, Wyn Kelley, Alvin Kibel, Christina Klein, Ruth Perry, Shankar Raman, Stephen Tapscott, William Uricchio.✣

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School of Engineering

Leadership Through Technical Excellence and Innovation

Thomas Magnanti

The School of Engineering has had, and continues to have, a profound impact on the world. Anchored on a tradition of accomplishment and yet forging novel initiatives in content and style, the School aspires to remain at the forefront of engineering innovation and sustain its research leadership.

Research in the School is broad and eclectic, ranging from engineering science to the creation of innovative products, and encompasses a wide variety of research themes and approaches, some pursued by individual investigators, others conducted through group projects or umbrella grants orchestrated by large research centers and laboratories. This blending of theory and applications and an openness to differing styles stand as hallmarks of the School's research and vision.

A Tradition of Accomplishment

Over the decades, the School, and more broadly the Institute, has:

• created numerous new fields of engineering inquiry;

• created the contemporary model of engineering science;

• pioneered the model of the modern research university with externally sponsored research programs, and a matrix organization of departments, laboratories, and centers; and,

• led in creating models for collaboration between academe and industry.

Through its research, MIT has contributed to many twentieth century innovations that have profoundly changed our everyday lives and the very fabric of society. The following examples are illustrative:

• In basic industries, the development of steelmaking and of equipment and processes for the production of gasoline and clean combustion for electric power generation.

• In medicine, early work on developing artificial skin, novel polymers used for wafers to deliver chemotherapy in treating brain cancer, microchips for the controlled release of chemicals ("pharmacy on a chip"), and modern technologies for artificial limbs.

• In aerospace, signal detection and analysis techniques used for very long-range communications, such as space exploration, and the design and development of the inertial guidance system for moon landings.

• In electronics and computers, analog computers, prototype of the Internet, magnetic core memory, the first workable public-key cryptographic system, computer time-sharing, and internet protocols (TCP/IP).

• In design and manufacturing, the basis for CAD/CAM.

MIT has not only been a pioneer in specific fields of engineering research, it has also created widely adopted research models. MIT arguably pioneered the modern research university as we know it today, having been chosen in 1940 as the site of the famous Radiation Laboratory ("RadLab"). Somewhat later, Dean Gordon Brown advocated the "research center" to encourage interdepartmental, interdisciplinary research. His concepts have helped reconfigure technical and engineering schools around the world. In 1973 the MIT Polymer Processing Program (PPP) became one of the first, if not the first, industrial sponsored research consortia at a university.

Looking Forward

The School continues to lead in creating and improving numerous technological systems and processes. It has embarked upon several initiatives aimed at sustaining its research leadership.

Partnerships

MIT's industrial and university partnerships, which foster and support significant interdisciplinary engineering research, have become an increasingly large component of the School's research portfolio. Either anchored in the School itself or often focusing largely on engineering content, these partnerships provide a broad funding base on topics that are of interest both to MIT faculty and to the Institute's industrial and university colleagues. The Dupont-MIT Alliance, for example, is creating new processes for novel biologically-based materials. Through the HP-MIT Alliance, faculty from several centers collaborate with HP researchers in the area of wireless communications. A major MIT-directed consortium to address global environmental challenges has emerged from the Ford-MIT Alliance; and the MIT-Microsoft Alliance has created new educational technologies and pedagogies. The Singapore-MIT Alliance (SMA) and Cambridge-MIT Institute (CMI) have brought together faculty from several departments to conduct research on such varied topics as advanced micro- and nano-materials, manufacturing, and high performance computing.

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Leadership Through Technical Excellence and Innovation

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Recent Institutional Initiatives

The Institute for Soldier Nanotechnology (ISN) is a multi-year research partnership with the U.S. Army and several other external organizations (currently Raytheon, Dupont, and Massachusetts General/ Brigham and Women's Hospital) to develop innovative, lightweight uniforms with novel functionality for the soldier of the future. It will draw upon approximately 35 core faculty and 80-100 graduate students to address, like the RadLab, an important national need.

Creating a new model for supporting research and interacting with industry, the Deshpande Center for Technological Innovation aspires to foster research on new and emerging technologies and increase interactions among MIT, individual entrepreneurs, innovative companies, and the venture capital community.

New Content Areas

Engineering is undergoing a significant transformation. And so is the School as it positions itself to assume a leadership role in several exciting new fields of investigation.

Bioengineering

At MIT we are creating a new discipline of biological engineering that might eventually parallel other fields such as chemical, electrical, and mechanical engineering. Building upon the molecular and genomic revolutions in biology, we seek applications in medicine and health care, pharmaceuticals, new materials, the environment, and other domains. For example, research in this area might create nano machines that identify and attack disease in the body, integrative systems that greatly accelerate the processes of drug discovery and development, or the means to grow new organs, blood vessels, and bones from a patient's own cells.

To celebrate the new millennium, the National Academy of Engineering announced its list of the top 20 engineering accomplishments of the twentieth century:

1) electrification
2) automobile
3) airplanes
4) water supply & distribution
5) electronics
6) radio & television
7) agriculture mechanization
8) computers
9) telephone
10) air-conditioning & refrigeration
11) highways
12) spacecraft
13) Internet
14) imaging
15) household appliances
16) health technologies
17) petroleum & petrochemical technology
18) fiber optics
19) nuclear technology
20) high performance materials

Engineering Systems

The creation of new technological systems and the social impact of technology have had an astounding impact on our lives. Today's research in engineering systems aims to better understand and subsequently improve large, complex systems. Two examples are reconciling the inevitable growth in world-wide demand for energy with potential environmental costs, and using modern information technologies to create products that are more timely, cheaper, and more responsive to consumer needs.

Information Engineering

Information, computation and communication in engineering – or information engineering – are driving forces underlying much of contemporary society and are becoming pervasive throughout engineering. For example, researchers are investigating instrumentation and the use of information systems and technology in biology. Other investigators are examining imbedded software in both satellite and airplane systems. And yet other researchers are studying the Internet, supply chain management, computational biology, computational materials, and simulation and optimization of complex systems.

Tiny Technologies

Research in tiny technologies includes both miniaturization – making technologies increasingly smaller – and nanotechnologies, the manipulation of atoms to create technologies measured in billionths of a meter. Over a tenth of our engineering faculty are currently creating such technologies as micro engines (turbines the size of shirt buttons), quantum-dot-based computation, carbon-nanotube transistors and interconnects, microphotonic devices, and molecular electronics.

Although these innovative arenas capture only a fraction of the School's forward-looking investigations, they establish significant new vectors for engineering education and research. Utilizing the tremendous talents of some of the world's most creative minds – our faculty, researchers, and students – we look to a future again significantly transformed and enriched by engineering innovations. The School of Engineering will certainly play a major role in shaping this exciting future.✣

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School of Science

Younger MIT Faculty Researchers Are Their Discipline's Future Stars

Robert Silbey

Research in the School of Science spans the space from string theory to cognitive science. The students and faculty of the School of Science carry out their research within six departments (Biology, Brain and Cognitive Sciences, Chemistry, EAPS [Earth, Atmospheric, and Planetary Sciences], Mathematics, and Physics), and a number of Laboratories and Centers (Center for Cancer Research, Center for Learning and Memory, Center for Space Research, Laboratory for Nuclear Science, Spectroscopy Laboratory). Much of this is interdisciplinary, including many collaborations with faculty in the departments in the School of Engineering.

Instead of giving a general overview of the research in the School, I would like to highlight the research of our younger faculty, who have recently begun their academic careers here at MIT, and who are the future stars of their disciplines. Unfortunately I cannot do justice to the research of *all* the young faculty, so I have chosen a small, representative group to highlight. I apologize to the others, any one of whom could have been chosen.

Angelika Amon, in the Biology Department, has been studying mitosis, an essential step in chromosome duplication and segregation. Early in mitosis, each chromosome pairs with its replicated sister chromosome and then becomes attached to one or other pole of the mitotic spindle. As mitosis proceeds, the connections between sister chromosomes are severed and motor proteins pull one chromosome of each pair to opposite ends of the cell. The final stage ensures that each daughter cell receives one copy of each chromosome. If cell division occurs before the chromosomes divide, diseased cells can result. How does the cell machinery prevent this from happening? Amon discovered that the interaction of two proteins, one bound to the spindle-pole body and the other localized in the daughter cell, were required to activate the last step of mitosis. This mechanism prevents cell division from occurring until nuclear segregation is complete.

Using computational methods, Chris Burge and his group in the Biology Department have successfully predicted the function of molecular sequences in messenger RNA (mRNA). Messenger RNA molecules typically contain strings of genetic material called exons, which code for proteins, and introns, which do not. Introns, like film outtakes, are removed from mRNA by a splicing mechanism that joins exons together. Surprisingly, the exons make up only a small percent of the genetic material in human cells. RNA splicing determines which segments in the lengthy stream of genetic material that makes up a gene end up being expressed and which do not. The new computational method can predict which sequences of genetic material get spliced out and which end up as the blueprint for life. They have found a way to predict which mutations in a gene's exons are likely to cause the exons to be skipped by the splicing machinery. Skipping of exons typically results in inactivation of the gene's product, which can lead to disease.

His [David Mohrig's] research leads to an understanding of how the processes governing tectonics and mass transport have changed the earth over geologic time. It has great significance to oil and gas exploration because some of these structures serve as large reservoirs for hydrocarbons.

David Mohrig's research, in EAPS, focuses on elucidating the geomorphic and hydrological processes involved in the evolution of terrestrial and submarine landscapes over 10,000 years or more. His approach involves integration of information from field studies of modern and ancient sedimentary systems, three-dimensional seismic surveys of subsurface structures, laboratory experiments on sediment-transporting flows, and numerical studies. His research leads to an understanding of how the processes governing tectonics and mass transport have changed the earth over geologic time. It has great significance to oil and gas exploration because some of these structures serve as large reservoirs for hydrocarbons.

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Younger MIT Faculty Researchers Are Their Discipline's Future Stars

Silbey, from preceding page

Kate Scholberg, a young physicist, is working in two large international collaborations, one (AMS) to place a particle detector in the international space station and the other (K2K) studying whether neutrinos have mass. These particles were assumed to have zero mass, but recent experiments and theories have suggested that they may indeed have mass. There are three kinds of neutrinos and the experiment measures the oscillation among these three by sending a beam of neutrinos a distance of 250 km through the earth from Tsukuba, Japan to the Super K detector. The discovery of non-zero neutrino mass is perhaps the most exciting discovery in particle physics in the past several years.

In the Chemistry Department, Peter Seeberger and his students have perfected a way to synthesize complex oligosaccharides, i.e., sugars, and to automate the process. Seeberger created an oligosaccharide synthesizer, which cuts the time required to produce extremely complex carbohydrate molecules by a factor of 100. The device has opened the door to a flood of potential applications for new research and disease treatments. Recently, he and his students used this approach to prepare a complex oligosaccharide that is structurally similar to the toxic carbohydrate found in the single-celled parasites that cause malaria. Injection of this synthetic toxin elicited an immune response in mice, making it an excellent candidate for clinical evaluation in humans. Application to related problems in human health, such as West Nile virus, can be envisioned.

Pawan Sinha, in the Department of Brain and Cognitive Sciences, is investigating how the brain accomplishes its remarkable feats of recognition, such as identifying distant faces. Besides being a fundamental challenge in neuroscience, this question is of great practical significance for creating artificial systems that can interpret their environment. Pawan is addressing two basic problems: What is the nature of object representations, and how are these representations learned? Using highly degraded inputs, Pawan and his students have determined some of the critical pieces of information that subserve recognition. Based on these results, they are formulating computational models that mimic human performance. To explore object learning, Pawan is studying children in India who have recovered sight several years after being born blind. This reveals how a brain that has just been provided access to visual information, begins to create representations for the task of recognition. This unique project promises to provide fundamental insights about brain plasticity and learning.

Pawan Sinha, in the Department of Brain and Cognitive Sciences, is investigating how the brain accomplishes its remarkable feats of recognition, such as identifying distant faces. Besides being a fundamental challenge in neuroscience, this question is of great practical significance for creating artificial systems that can interpret their environment.

Dan Spielman is a young mathematician who studies theoretical computer science. Recently, he introduced smoothed analysis, a new framework in which to analyze algorithms, and demonstrated that the good practical performance of the simplex method, which has been effectively used since the 1950s to solve optimization problems in numerous industrial applications, could be understood in this framework. In smoothed analysis, one analyzes the performance of an algorithm assuming there is slight imprecision in its input. This assumption is reasonable in many real-world applications in which data is derived from experimental measurements. While an algorithm with a good worst-case analysis will perform well on all inputs, an algorithm with a good smoothed analysis will perform well on almost all inputs in every small neighborhood of inputs. One surprising corollary of this work is that experimental error in the data input to an algorithm can actually improve an algorithm's performance.

These and the other young faculty who have begun their careers at MIT in the past few years, are changing the way we think about science. They are the future and make MIT the exciting intellectual community it is.✣

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Sloan School of Management

Research@Sloan

Richard Schmalensee and Donald Lessard

When the MIT Sloan School of Management was founded in 1952 (as the School of Industrial Management), it was with the intention of changing the way management was done.

The foundation for this bold ambition was the belief that important management problems could be solved by the rigorous and creative application of tools from basic academic disciplines, including applied mathematics, economics, psychology, and sociology. This discipline-based and problem-focused approach to management research and education set the Sloan School apart. It also changed the way management was – and is – taught and practiced. This approach remains one of Sloan's greatest contributions to the business world.

Since those formative years, Sloan research has been a continuing source of innovation that has advanced both theory and practice.

• Doug McGregor's famous distinction between "Theory X" and "Theory Y" argued persuasively that employees should be seen not as shirkers needing control, but as creative agents needing to be empowered. This was an altogether new way to think about managing people. Its impact, and that of the behavioral scientists McGregor brought to Sloan, has been deep and broad.

• The remarkable work on option pricing by Fischer Black, Bob Merton, and Myron Scholes has had a dramatic impact on the structure and operation of global capital markets. Work on corporate finance by Franco Modigliani, Stew Myers, and others reshaped business thinking about capital structure and investment decisions.

• Finally, work on quantitative marketing models by John Little, Al Silk, Glen Urban, John Hauser, and others has changed the way companies approach the design and launch of new products. The ASSESSOR model alone has been used in nearly 5,000 pre-test-market studies of new packaged goods.

Today, Sloan research continues to shape how the world teaches, understands, and practices management. Increasingly, our work builds on MIT's distinct intellectual excellence and entrepreneurial culture. Sloan's research excellence is widely recognized. The major ranking of business schools with an explicit focus on research, the *Financial Times* survey, ranked MIT Sloan first in research in 2000 and second in 2001, against schools with faculty two and three times its size, and individual faculty regularly garner top awards in disciplinary and professional arenas. Recent research awards include:

• Steven Eppinger (and student Soo-Haeng Cho) received the 2001 ASME International Design Theory and Methodology Best Paper Award for a paper entitled "Product Development Process Modeling Using Advanced Simulation."

• John Hauser won the 2001 Charles Coolidge Parlin Award of the American Marketing Association, joining earlier Sloan winners Glen Urban and John Little. This award recognizes his many contributions to marketing research, including his current work on the "Virtual Customer" initiative, discussed below.

• Stewart Myers (and co-author James Read) have developed new ways of assessing the amount of capital required to support risk taking in various domains, a key building block in risk management. Their paper, "Capital Allocation for Insurance," has been selected by The American Risk and Insurance Association as a winner of the 2002 Robert C. Witt Research Award for outstanding feature article published in the *Journal of Risk and Insurance* during the previous year, as well as for an award by the Casualty Actuarial Society.

• John Sterman and Nelson Repenning won the 2001 *California Management Review's* Accenture Award for the article "Nobody Ever Gets Credit for Fixing Problems that Never Happened: Creating and Sustaining Process Improvement," continuing their work on systems dynamics modeling of organizations. Repenning also has won the Thomas P. Hustad Award for the best paper to appear in *Journal of Product Innovation Management* in 2001 for his paper "Understanding Fire Fighting in New Product Development."

A sampling of the most recent Sloan working papers (published by the Social Science Research Network (SSRN) in the MIT Sloan School Research Abstracts Journal <http://www.ssrn.com/link/MIT-Sloan-School.html> shows a breadth of topics and approaches:

• "Isotone Equilibrium in Games of Incomplete Information" (David McAdams, Applied Economics)

• "Skill or Luck? Biases of Rational Agents" (Eric Van den Steen, Applied Economics)

• "E-Business at Delta Air Lines: Extracting Value from a Multifaceted Approach" (Jeanne Ross, CISR)

• "The Allocation of Resources by Interest Groups: Lobbying, Litigation, and Administrative Regulation" (John de Figueiredo, Strategy and International Management)

• "Adjustment Costs, Learning-by-Doing, and Technology Adoption under Uncertainty" (Anna Pavlova, Finance)

• "Dynamic Valuation: Preference Changes in the Context of Face-to Face Negotiations" (Jared Curhan, Negotiations)

• "An Equilibrium Model of Rare Events" (Jun Pan, Finance)

• "Shifting Innovation to Users via Toolkits" (Eric von Hippel, Management of Technology, Innovation, and Entrepreneurship)

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• "Trade Linkages and Output-Multiplier Effects: A Structural VAR Approach" (Kristin Forbes, Applied Economics)

• "Solving Project Scheduling by Minimum Cut Computation" (Andreas Schulz, Operations Research)

• "Determinants of the Informativeness of Analyst Research" (Richard Frankel, S. P. Kothari, and Joseph Weber, Accounting)

• "Problem Investigation in High-Hazard Industries: Creating and Negotiating Learning" (John Carroll, Organization Studies)

Given the range of disciplines and topics involved, there is no simple way to characterize research at Sloan. A useful first cut, though, is along three dimensions. These are:

1) Broad disciplinary areas around which the faculty is organized – behavioral and policy sciences, economics/finance/accounting, and management sciences,

2) Management topics addressed – including innovation and new product development, strategic organization, asset markets and international linkages, entrepreneurship, digital business models, the interaction of informational technology and organization structure and performance, impacts of accounting information, and the changing relationship between work and family, and

3) Centers in which researchers collaborate – many of which involve colleagues from across the Institute, including the Operations Research Center, the Center for Energy and Environmental Policy Research, the Joint Project on Global Change, the Center for eBusiness, the Center for Information Systems Research, the Laboratory of Financial Engineering, the Center for Coordination Science, and the Institute for Work and Employment Relations, among others.

Much of Sloan's research addresses current management issues while drawing on and deepening fundamental knowledge. The "Virtual Customer" initiative, for example, has the potential to transform product development by engaging customers directly in the design process over the Internet . . ..

Much of Sloan's research addresses current management issues while drawing on and deepening fundamental knowledge. The "Virtual Customer" initiative, for example, has the potential to transform product development by engaging customers directly in the design process over the Internet through the use of sophisticated algorithms that allow designers to elicit consumer preferences efficiently. Similarly, research by the accounting group on the impact of analysts' rating of underwriting and other potential conflicts predates the current public focus on this topic and brings informed opinion to the debate. A significant portion of Sloan research, though, is motivated directly by fundamental puzzles in the various disciplines. An interesting example is recent work by Simon Johnson showing that social institutions in developing nations have importantly affected development success and that the nature of these institutions can, in turn, be explained to an important extent by settler mortality rates in early colonial times.

According to a recent faculty survey, the greatest obstacle to research at Sloan is the scarcity of blocks of time that can be dedicated to research. This reflects the intensity of teaching in Sloan's broad array of programs: the second-largest undergraduate major at MIT, a substantial MBA program that accounts for about half our teaching, the LFM [Leaders for Manufacturing] and SDM [System Design and Management] programs with Engineering, two degreed executive programs, and a PhD program.

Sloan faculty, on average, teach many more students than others at MIT. Efforts are currently underway to reduce the number of subject preparations per faculty member to permit most to concentrate teaching in a single semester, and to build stronger links between research and education. Funding also remains a challenge. Sloan obtains about $10 million per year in sponsored research, with roughly 80 percent coming from corporations. While the sponsored research level per faculty member (about $100,000) is low by MIT standards, it is well above that at any other major business school. (Most of our competitors can support essentially all research with School funds.) This level of corporate support requires considerable faculty involvement in sponsor relations, but it does have the benefit of requiring that researchers focus on practical impact as well as fundamental understanding, as "mens et manus" directs.

A major gift from an alumnus and his wife will enable us to take a large step toward addressing these challenges. It will provide research funding to a group of senior and junior faculty working at the intersection of strategy and organizational design, as well as providing these faculty with the time to collaborate, beginning with "listening in" on each others' courses. It will also support greater engagement by students in the research process and quicker, more effective incorporation of research results into courseware. We hope and expect to launch similarly focused efforts in other strategic areas.✣

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Evolving Research at MIT

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years MIT has experienced real research growth. During Fiscal Year 2002 (ending June 31, 2002) our research volume grew by almost 10% from the previous year, now standing at $448M. By way of comparison, FY2001 showed a growth rate of 6.1%.

Several reasons lie behind this growth, all characterized by an essential theme: the constant effort to make MIT attractive to the very best graduate students and faculty, and to enable these researchers to go where their curiosity leads them. The successes developing within our research environment result from the creativity of our faculty and staff and the Institute's support of their research. Important stimulants include, first, the renewal of our faculty resulting from 80 of our colleagues taking advantage of the early retirement program in 1996. Second, is the growth of new disciplines and new interdisciplinary research areas. Third, the direct subsidy of graduate research education helps us continue to attract the best students into our graduate programs and make MIT's cost of research competitive with programs in our peer private research universities. Finally, the increase in graduate student housing, the upgrading of research facilities in many research areas, and the creation of totally new facilities in others, also have contributed.

The MIT faculty is changing. Of the approximately 964 faculty members who are leading us into the fall semester, 318 have joined us since July 1996. The schools of Science and Engineering alone count for 172 faculty colleagues belonging to this cohort. These new colleagues have brought with them new ideas, new research directions, and new collaborations across traditional boundaries. The Schools and the Office of the Provost are emphasizing the need to support these younger faculty and their new initiatives. The dividends are apparent. As an example, the 29 faculty who came together to win the U.S. government's $50M award for the Institute for Soldier Nanotechnology reveal an average time on the MIT faculty of 11.6 years, as compared to 15.2 years for the rest of the faculty in the schools of Science and Engineering.

The new resources the Institute is devoting to graduate education and research constitute another substantial set of ingredients. Most important is our system for subsidizing graduate research assistants on research contracts and grants, through cost-sharing 65% of the academic year tuition and 100% of the summer tuition. At tuition rates for this fiscal year, these subsidies amount to $27,500 per student or over $68.3M in subsidies forecast for this year. In addition, this fall the Presidential Graduate Fellowship Program will support 170 first-year graduate students across our five schools and help us remain competitive, especially in those areas of scholarship highly subsidized in our peer institutions' graduate programs. The MIT budget directly supports this fellowship program, and plans to raise endowment to support it more strongly are being developed. Endowment commitments have been very hard to find. Currently we have endowment support for only 70 fellowships for new students in the fall of 2004. The Provost's Office sees continuing this program as one of its highest priorities.

Upgrading the research infrastructure is also near the top of the list of priorities. To date, most of the improvements have come as renovations of space for new faculty, although other pockets of renovation are ready for inspection. For samples, take a look at the Hatsopoulos Laboratories in Mechanical Engineering (on the second floor of Building 3, occupying 5,600 sq. ft.), or the sixth floor of Building 37 in the Center for Space Research. In the next several years, significant new research and teaching spaces in facilities will appear in the Ray and Maria Stata Center, the Brain and Cognitive Science Center, and the renovation of Building 18 for the Department of Chemistry. These new facilities represent commitments by MIT and our supporters to the increased importance of information sciences in the years ahead, and to the strategically important push by MIT into neuroscience as led by the Department of Brain and Cognitive Sciences, the McGovern Institute for Brain Research, and the Picower Center for Learning and Memory. The renovation of Building 18 for the Chemistry Department represents the type of difficult, infrastructure upgrade that is needed to keep our facilities competitive for world-class research.

The campus is also witnessing an exciting, substantial increase in life science research. While others are better able to describe the opportunities for societal and economic impact caused by the explosion in our understanding of living systems, it is clear that research in life sciences is quickly spreading from its traditional base in modern biology and impacting much of science and engineering. The creation of the Division of Biological Engineering has catalyzed much of this activity in the School of Engineering, forging links to other engineering and science departments. The Division of Health Sciences and

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Evolving Research at MIT

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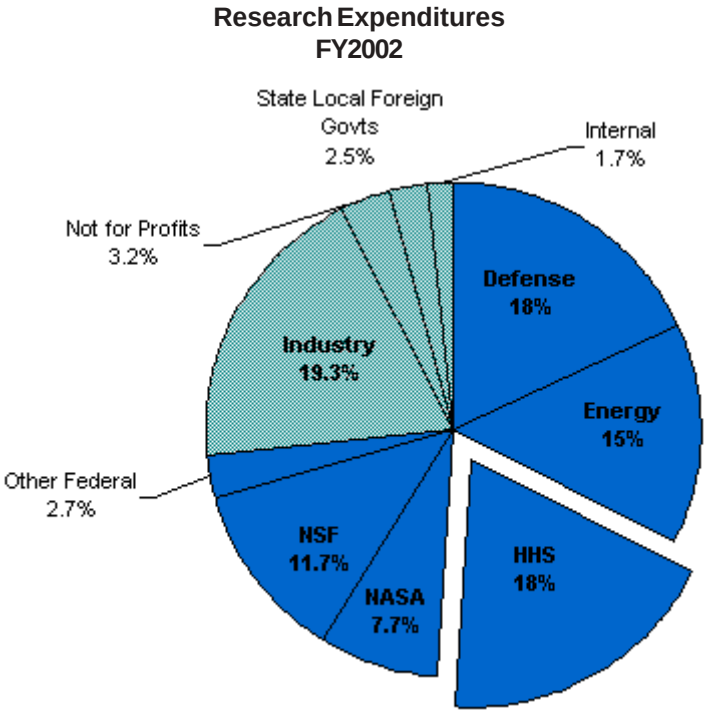
Technology (HST) constitutes the academic bridge between MIT and Harvard Medical School. The doubling of the NIH research budget from 1992 to 2002 has fueled the life sciences research engine. The promise for the future is bright. Growth in our research volume in life sciences is very evident in the figure, in both the increased fraction of research supported by NIH and the increase in research volume of the life-science related units. The total research volume represented here is $448M. The $83.5M from Health and Human Services (HHS) represents a 38% increase over 1997, even more remarkable when compared to the approximately 20% decreases in Department of Energy and NASA funding, and the almost flat funding from the Department of Defense over the same time period.

The chart does not include the research volume of the Whitehead Institute for Biological Research (WIBR), which was $135M in FY2002 ($105M went to research carried out by the MIT-Whitehead Human Genome Center) and led by 15 of our faculty colleagues, and the research funded by the Howard Hughes Medical Institute, which was $12M in FY2001.

The shift into life sciences and other experimentally intensive disciplines comes at a price. Biological laboratory facilities are needed where none existed before (sometimes I think every faculty member will sooner or later want a tissue culture facility or a fume hood) and new types of experimental infrastructure are also necessary. We are working to develop these experimental facilities, much as we did for new facilities in physical sciences in the decades before. Examples include the MIT-Harvard Medical School Facility for High-Field NMR, where a state-of-the-art 900 MHz system is under construction; the MIT-Whitehead Biological Imaging Center in Building 24 that will be the home of a high-field cryo-TEM; and the collaboration with the Harvard Medical School and Massachusetts General Hospital to form the Martinos Center for Functional Imaging. All of these initiatives have very substantial external support.



Industrial support has also strongly contributed to the growth of our research volume, which has grown from $56M in FY1997 to $86M in FY2002, an increase of 55%. This support has come in the form of traditional, single-investigator grants and larger research partnerships. It is interesting that out of the eight research partnerships that MIT has established, four heavily involve life science research.

One question that we need to debate is the extent to which growth in research is healthy or even sustainable for MIT. We should recall that the increased research activities and size of our graduate programs are being administered by an almost unchanging number of faculty and senior research staff. A growth rate at a couple of points above the CPI (Consumer Price Index) would seem appropriate if a research-intensive university like MIT is to absorb the higher inflation rate; the Higher Education Price index typically runs 2 points higher than the CPI.

It is also clear that MIT still faces an enormous amount of work in the future if we are to continue to improve our infrastructure for research, and to continue to identify the resources needed to support graduate research and education. Even simply maintaining our competitive position will be difficult, because additional internal resources will be scarce. Equity markets have suffered badly and with them MIT's financial flexibility. The need for resources for new faculty will continue unabated, first, because we must do the very best we can to launch their careers, and second, because this is the very best investment we can make: these colleagues' energy will ensure that MIT's research and education efforts will continue to develop new research frontiers.

The wonderful support of Lydia Snover, assistant to the Provost for Institutional Research, in the preparation of this note is gratefully acknowledged.✣

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An Interview with Alice P. Gast

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FNL: So do you focus specifically on labs and centers as opposed to departments?

AG: I try to work within research in general but I also care for and support a number of labs and centers. I view the position as continuing to be the champion of interdisciplinary research. As with previous Vice Presidents for Research, I can work with Deans and we can pursue initiatives together; the centralized administration and collegiality here makes that quite easy to do.

FNL: So what do you do, per se? Part of it seems to be that people need an integrated multi-disciplinary push in the right direction, but how do you even find that out?

AG: I do a number of things in my position. I'm responsible for 14 interdisciplinary labs and centers, and I do take that very seriously, and I serve on Academic Council, and feel like I represent the research side of the Institute. I've been responsible for issues of research policy, and that can be both interdisciplinary or at any level that it's an institutional matter of policy. I also serve on the space planning committee [CRSP]. I serve on what I would call the strategic level of CRSP, and my goal is to think broadly and on the research side, dealing with institutional priorities for space utilization innovations, new buildings, and to think about how we can best serve the research teams' interests.

FNL: As part of research policy issues, do you have any connection to distance learning or the Web?

AG: I haven't been integrally involved yet in OpenCourseWare, although I'm peripherally involved with some of the issues that they're dealing with regarding copyrighting and the licensing of educational materials.

FNL: What are some of the other policy issues?

AG: Environmental health and safety is a very important one that I view as a key issue.

FNL: How much of that is internal, and how much is mandated?

AG: From my work with the Ad Hoc Committee on Environmental Health and Safety, I view a lot of the synergy and activity as internal. I realize that there is external pressure to meet the consent decree with the EPA, but I would say at this point there's a very broad recognition of the need for an Institute-wide system that works well for all the different parts of campus.

FNL: So do you work with OSP [Office of Sponsored Programs]?

AG: I do. Research policy also involves research grants and contracts, and so I work with Julie Norris in OSP on issues of conflict of interest.

FNL: How much of your time have you spent on that? (There's no video camera today so the readers can't see you roll your eyes.)

AG: It varies. [LAUGHTER] A big fraction of time.

FNL: And this is talking about individual cases, waivers, requests? It seems the boundaries have been pushed a lot in recent years, if not decades. There are issues here going back to when Whitehead was established, and now there are cases where more and more of industry wants academia to get involved in doing their work.

AG: Yes, that's very definitely a tone and a trend I see nationally. Industry views that now universities can help them with their research and development.

FNL: It's classically been done in Europe. European scientists often are funded heavily by industry. Yet certain desires of industry can fly in the face of our educational objectives.

AG: Yes, MIT has very high standards for openness and educational objectives regarding research.

FNL: So you're really the person who's the watchdog.

AG: I'm the gatekeeper. And I was very pleased with the document that Sheila Widnall's committee put together on classified research. They have a chapter, a small chapter, with recommendations about industrial corporate sponsored research. And in general, you'll find that MIT's policies are not explicitly documented in some of these areas, and the committee's report actually provides very nice guidelines that do lay it out in black and white. Their charge to continue with more discussion on these issues is a very important one.

FNL: What are the sanctions that tend to be levied by your office or anybody else's? To what extent is there action taken when breach of ethical procedures occurs?

AG: Well obviously, they come in case by case. And most often, I've dealt with issues regarding grants and contracts that we cannot accept because they do not meet our conflict of interest standards, or there are issues around publication rights and things like that. Most of those issues in the contracts were actually negotiated by OSP and our intellectual property counsel, and so I only see them if there's a problem.

FNL: And it's up to them to alert you of potential problems?

AG: Right.

FNL: So, it's not up to the faculty to check with you ahead of time before they try to sign something away. Since this interview is for the *Faculty Newsletter*, is there anything you'd like to alert the faculty to concerning their responsibilities in this area?

AG: I would suggest that faculty do and can continue to seek the advice of our Sponsored Projects Office, our Senior Counsel for Intellectual Property, or my office.

FNL: So where would the faculty go? *Policies and Procedures*? You said those seem not to be as well spelled out as you'd like.

AG: The policies and procedures are not very explicit on some of the details on issues that we deal with.

FNL: Whereas the Widnall report . . .

AG: It provides some guidelines, and faculty can come to my office. They can come to the office of the intellectual property counsel. Traditionally faculty have gotten a lot of guidance from [Senior IP Counsel] Karen Hersey and now her replacement in dealing with these questions. We strongly encourage faculty to get advice on non-disclosure and confidentiality arrangements. There are plenty of resources here through the Office of Sponsored Programs, the Office of Intellectual Property Counsel, and my office.

FNL: What about the changing R&D on campus? You haven't been here that long, but basic research now seems to be more frequently sacrificed, or industry certainly would like us to sacrifice it, for the end product. It's probably not your job to change it per se, but is that on your radar screen?

AG: It is on my radar screen, and partly from my discussions with various representatives of industry in various venues. But my personal view is that industry should engage in cooperations with universities when they want to gain a better fundamental understanding of something and when they would like to have that knowledge readily available to the entire world. They should engage in those collaborations where there are areas of common interests, realizing that the product will be fundamental research, publications, and students. Traditionally, one of the great assets that an industry/university collaboration had was that students would be exposed to some of the issues that arise in applications of their research and they would learn about industries in more detail. Industries would be exposed to a student body and have them trained in areas that they were interested in, and there'd be a lot of common interests in the prospective hire's perspective.

FNL: So in terms of deliverables, is it part of your job to negotiate these contracts?

AG: No, I don't do that. The Office of Intellectual Property and the Office of Sponsored Programs would handle that. I think that in recent years intellectual property has become a much bigger part of the equation. And so industry moves into a relationship with a university expecting not only research results and knowledge and students, but also intellectual property. I think perhaps that was partly driven by a lot of young companies who had more intellectual property than real property – product. And when you start dealing in ideas and ideas are what are fueling your company, then the intellectual property becomes very valuable to you. I think that's an unfortunate trend . . .

FNL: So does the average investor.

AG: [LAUGHTER] Recent stock market results have made that clear.

FNL: Has anything specifically changed in your area as a result of 9/11?

AG: Oh, very much so. Among the first thing that comes to mind are issues regarding security. We add to the already active efforts in environmental health and safety

An Interview with Alice P. Gast

Continued from preceding page

the aspect of security; making sure that our research materials and our research results are safe and secure. That is the basic reason for the bioterrorism legislation that many people have heard about if they happen to work with what are termed select agents that could be considered a hazard or dangerous if they got into the wrong hands. And we've been responding to that new legislation.

FNL: Are there other post-9/11 issues?

AG: Yes. The International Scholars Office reports to me and the International Students Office reports to me via the Dean for Graduate Students, and so I've spent a lot of energy and effort thinking about how we deal with post September 11th issues. In particular, the INS has speeded up its implementation of a database system.

FNL: There are stories of post docs who have been told that, if they pay a $1,000 fee, the rate at which their visa renewal application will be handled will be fast-tracked. They were told so 3-6 six months after they had conscientiously sent in all their paper work and fees. They were told that $1,000 would put them at the front of the line.

AG: There are delays now in getting visas. And the International Scholars or International Students Office are very good about warning people of those delays and trying to help them prepare in advance for delays that can occur in visa applications now, and even denials. We have had some fraction of denials, too.

FNL: What about foreign students in general?

AG: What I get is more of a general issue – calls from newspapers and radio programs talking about the foreign student issue and how we're dealing with it or what we think. And you know, I've expressed how much we value our foreign student population.

FNL: That's not the spin they often have.

AG: Right. But I think it's important that institutions like ours stand up for international student and scholars.

FNL: Any other post–9/11 issues?

AG: I also co-chair, with Associate Provost Claude Canizares, the Committee on the Protection of Human Life and Infrastructure, formed by Chuck Vest to assess what, if anything, MIT would like to do or should do to respond after September 11th. And we're launching a new Website this September. We're going to use that Website as a means of communicating what we already do that is related to issues of terrorism and to, in some sense, raise consciousness with other faculty doing research who, with a little bit of change of focus, could contribute quite a bit to this War On Terrorism.

FNL: Do you see this whole area as a significant opportunity for research projects for the faculty?

AG: I believe it will be. I don't think it's going to go away. And I think it's appropriate for faculty to assess their interests and their concerns and whether they can apply their talents to these problems.

FNL: There was no national budget for this, and they continue to reorganize the plan.

AG: Yes, the national organization has certainly not been swift, and so to some extent, nobody has really known what to expect or where they should be focusing their attention. The Branscomb-Klausner Report has come out, which is a high level National Academy panel put together to focus on issues of counterterrorism, and so there are many recommendations of research areas or areas needing more attention in that report.

FNL: It's interesting that this may actually be an opportunity, in a very idealistic sense, perhaps to unify the campus more, not simply the different engineering or science disciplines, but really bringing in the whole Institute – humanities, architecture, etc., in pursuing this unified goal.

AG: One of the issues or recurring themes is, what I would use is the term the "root causes" – issues of the whole international studies area and how one can start to take a global view as one does with other large problems. And MIT is notoriously good at solving large-scale problems at systems levels.

FNL: The question of centers and labs – how do you see their evolution? Are there some that should be closed down?

AG: I would say that there is an evolution in labs and centers, and the Provost and I are very interested in trying

to foster new areas and think critically about how we're dealing with the more mature labs and centers. In particular, obviously, the Institute for Soldier Nanotechnologies is a new opportunity and a new interdisciplinary activity. It is an exciting institute with a contract from the army and a new facility here on campus; it will then evolve after the contract is over. And since it is interdisciplinary, it will report administratively to my office. The director, Ned Thomas, will also sit on Engineering Council because it has a strong link to the School of Engineering.

FNL: Any others?

AG: There's the Martinos Center, a medical imaging center involving a collaboration between MGH and MIT.

FNL: Do you see them as fundamentally different? There are always new centers and they have new ideas or laboratories – but are we really dealing with a fundamental paradigm change or not?

AG: I would say, looking at national research again, that interdisciplinarity is important. And I would say from the complexity of the problems being addressed, if you think about the types of work that people are doing in the forefront of biological sciences, for example, there are many, many areas where you need cross-disciplinary activities.

FNL: So do you think it's a valuable exercise for an institution to set up interdisciplinary programs and find people who can participate for a given period of time, as opposed to the general question of is interdisciplinary research worthwhile?

AG: Well, I do believe interdisciplinary research is worthwhile, and I do think that you need to maintain strong disciplines for faculty to come to collaborations with the appropriate tools and expertise. But it's when you do bring researchers together in a fruitful collaboration, as we've seen over and over again, that a lot of interesting new things can come out. And so, there's a balance between maintaining their disciplines so that you have your core competencies represented by the faculty, students, and research staff, but at the same time you nurture them, or make feasible and possible their interactions so that they can have productive collaborations unencumbered by any boundaries put up by the institutions.

FNL: The model in a lot of places is to bring people together from different disciplines into collaboration, and at a certain point in the creative development of the project the expertise that one really needs has to come from outside. And yet frequently funding agencies expect that the collaboration should take advantage of those resources that are nearby, because it's easier and cheaper. Yet often this perspective forces a certain mediocrity in performance because it's not the right match, but you do it because it's convenient. What do you think this is doing to the research environment?

AG: I don't see them as in opposition. I would never want to prevent an inter-institutional collaboration. But I think what the Institute has to think about is what they can provide to make these things easier and more productive. And you mentioned facilities, and that's one of the key things that is represented in the Soldier Nanotechnologies institute – central shared facilities where you can bring together people working on complex problems with extensive and state-of-the-art equipment.

FNL: Let's change the subject a bit. You came from Stanford; how about a little comparison between there and here.

AG: Well, I see MIT as a very centralized administration with a lot of individual autonomy. The faculty here have tremendous autonomy and authority, but the administrators do work together in a very centralized fashion. And I say that referring to Academic Council. I'm very impressed with their structure, the way they review promotions and appointments; they review all of them with great care and spend a tremendous amount of time, in fact, together on these issues – issues of concern to the Institute. Meeting weekly and spending so much time together, viewing the wide variety of issues and situations that come from across the Institute I think is a very collegial process. It brings people to a very deep understanding of how the schools operate, so that each dean has this broad view of the other schools.

FNL: It wasn't always necessarily like that.

AG: There's an Institute-level concern, and then there's the understanding of the differences that you have across campus units. It also makes it very easy to do things. I feel like I know the Dean of Science and the Dean of Engineering and the Deans of all the schools quite well. If I need to try

An Interview with Alice P. Gast

Continued from preceding page

to get something done between two schools, I can pull them aside on a Tuesday morning and we can talk for five minutes and something will happen. I don't view Stanford as quite so centralized. I view the schools as having much more independent authority. I was working very hard on the Clark Center for Biomedical Science and Engineering at Stanford. And it brings together in a very nice atmosphere of collaboration and communication and openness, people from Engineering, Medicine, and Science. But I feel that the structure of the administration there made it a bit more difficult to get the three schools together than it would have been at a place like MIT.

FNL: We could ask about the weather and then Stanford could get a plus on their side.

AG: Actually, I should preface this by saying that I have great respect for Stanford and thoroughly enjoyed my 16 years there. Leaving was a very difficult decision for me.

FNL: Well, we hope you're happy here.

AG: I'm very happy here. It has a lot of similarities to Stanford. Both places have very energetic and high intensity faculty. They share an eagerness to try new things and a boldness in experimenting. Stanford was embarking on a very exciting new experiment in bringing really disparate parts of campus together; and we could see very quickly how just bringing people together to get to know one another caused them to start a new collaboration three years before the building would even open! So I saw the power of having funds and facilities to bring people together to get to know one another from many different parts of campus. And I think that's been a long tradition at MIT. MIT has labs and centers that have brought people together from different parts of campus for a long, long time and they have a lot of different models for how to do that and you've alluded to some of them. And maybe they're all experiments, but they're all by and large working well, and so it's very gratifying to see all the different ways that research happens.

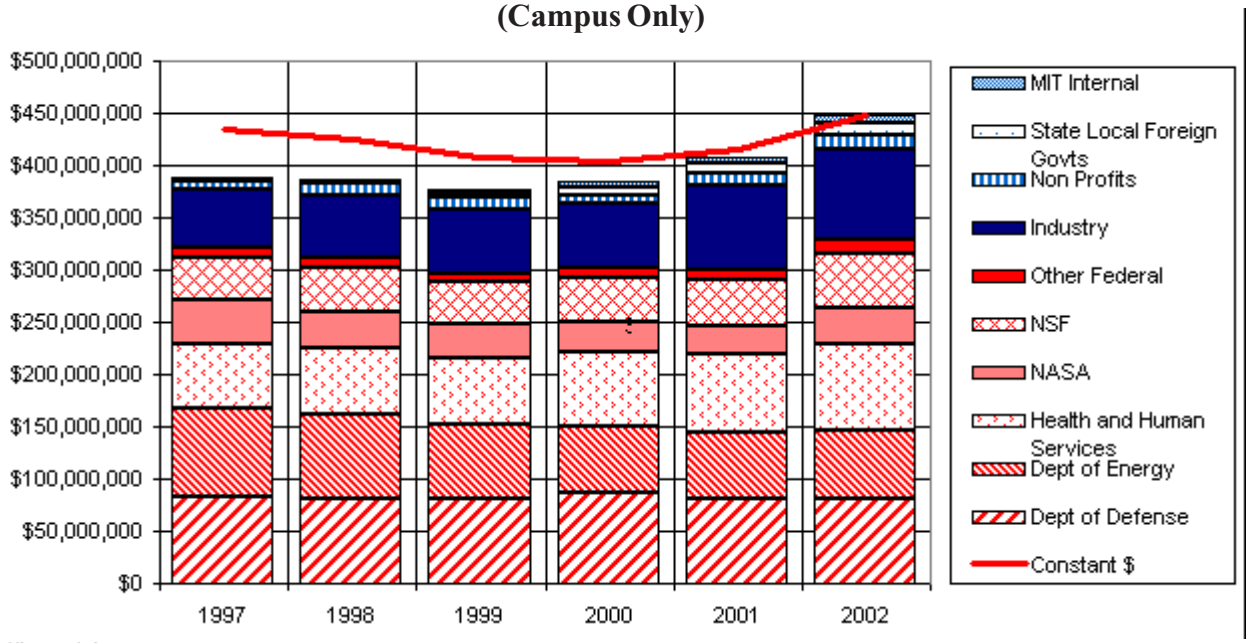
FNL: Is there anything you would want to say to the faculty that we haven't covered?

AG: My door is always open. I like to hear anybody's ideas about new ways of pursuing research or collaborations or any interdisciplinary activities. I look forward to more positive interactions with faculty and I've really enjoyed my work at MIT so far.✣

M.I.T. Numbers

Research Funding

(Campus Only)



Source: Office of the Provost

The Changing Nature of Research at MIT

Julie Norris

[Julie Norris, director of the Office of Sponsored Programs (OSP), discusses how changing regulations from research funding sources affect MIT faculty.]

MIT's research activities are wide ranging and ever changing. The distribution of funds between and among the various sponsoring organizations indicates how some of these activities have changed. [See MIT Numbers, back page.]

The most dramatic shift has been the increase in research volume from non-federal sources, particularly that from industry and other for-profit entities. In FY 2002, non-federal sources accounted for 38% of the total research volume at MIT; the 62% from federal sources is lower than that of most other large colleges and universities. This is partially due to the fact that MIT does not have a medical school, but it is also partially responsive to the emphasis the Institute has placed recently on expanding its research base and encouraging the development of large partnerships and collaborations (such as DuPont, Ford, CMI, and Singapore). At the same time, MIT continues to support and encourage the development of multi- and interdisciplinary laboratories to address cross-cutting research issues from multiple perspectives.

While MIT has grown its industrial research enterprise, the federal government has provided significantly increased funding to the National Institutes of Health (NIH) and has provided selective increases to the National Science Foundation (NSF). MIT's strong growth in both these agencies in FY02 testifies to the broad base of funding for the research enterprise at the Institute.

This increased funding has, however, also meant an increase in the complexity of the rules and regulations that govern federally funded (and some corporate funded) research. Increased oversight is certainly a by-product of this growth in research. Changes seen just in the last few years demonstrate the point. For example, researchers submitting proposals to the National Science Foundation and the National Institutes of Health now must submit formal disclosures of certain financial relationships; individuals utilizing human subjects in research must demonstrate via an on-line examination knowledge of the federal regulations relating to humans as subjects; individuals seeking to export certain technology, software, or information abroad must be aware of and comply with regulations relating to export controls. These are all time-consuming activities that detract from the time researchers have to do research.

However, the good news is that electronic research administration has provided some significant reductions in time needed to accomplish certain research-related tasks. For example, the search for research opportunities is now automated; individuals may receive information about research opportunities in fields they designate via e-mail every day of the year. Additionally, led by the NSF's FastLane System, the major research agencies have embarked on the development of automated proposal submission systems. Federal regulations require that agencies be able to accept electronic proposals by the end of CY 2003, and many agencies are developing systems (or have systems in place) to do so this year. Required annual and final technical reports are now routinely submitted electronically by researchers, and agencies are beginning to make awards electronically.

MIT is viewed as a national leader in the area of electronic research administration. Our COEUS system (for award management and as the Institute's feed to the accounting system) has been licensed by more than 80 other higher education institutions across the country. It is the model for the data included in awards now made by the Office of Naval Research. At the present time, MIT is piloting a research proposal development, routing, and submission component of COEUS that will allow MIT faculty to develop proposals, multi-year budgets, route those proposals through necessary Institute offices, and have OSP submit them to the agency electronically.

This system allows faculty and researchers to create the technical and scientific part of a proposal, letting administrative personnel in the originator's department create one or multiple versions of the budget. Once the technical proposal and budget are completed, the researcher "submits" the proposal electronically to the Institute. At the time of submission, the investigator responds to certain questions (about humans, animals, conflicts of interest, need for space, etc.) that replace the current routing sheet. Once completed, the persons who need to review the proposal (and this may vary depending on the specific proposal) are notified that a proposal is ready for review. These individuals can access the proposal electronically for review and approval. Once the proposal has all required reviews completed, it reaches the Sponsored Programs Office for final review and electronic submission to the sponsor (or for printing, if necessary). More information on this system, and requests for additional pilot units, will reach departments shortly.✣

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Research-in-Progress

Integrating Work and Family Life: Research at the MIT Workplace Center

Ann Bookman

[Ann Bookman, executive director of the MIT Workplace Center, discusses research pertinent to current needs of the faculty.]

The MIT Workplace Center, based at the Sloan School of Management, was founded in July, 2001 with a three-year grant from the Alfred P. Sloan Foundation. It is the seventh university-based center established by the Sloan Foundation to study the lives of dual-career, middle class families. It is the first such center to focus on the workplace, and the first to combine research with experimental interventions for change in selected companies. The Center is co-directed by Professors Lotte Bailyn and Thomas Kochan. Dr. Ann Bookman, a social anthropologist, is executive director, and Dr. Mona Harrington, a political scientist, is program director.

The approach taken by the MIT Workplace Center is based on two distinctive strands of scholarship and policy analysis. First, we hope to contribute to a growing literature on work redesign. For over 10 years, Professor Bailyn and colleagues have pioneered innovative approaches to work organization, advancing the possibilities for work-family integration and gender equity. She says, "After collaborating with employees and managers in many companies, I believe it is possible to design new work systems that promote the effective performance of firms and the well-being of employees, their families and communities. We are taught that we have to choose between the two – my research suggests that 'win-win' solutions are within our grasp." The MIT Workplace Center will address the problem of the "one size fits all" workplace. By engaging interested parties in the redesign of work systems and employment practices, we hope to offer new approaches to meeting the diverse needs of diverse families.

Second, our work is informed by the framework set out in a recent report, "Integrating Work and Family Life: A Holistic Approach," co-authored by Lotte Bailyn, Thomas Kochan, and Robert Drago. Written with the participation of a small, national group of academics and practitioners called the Work-Family Policy Network, the report reviews the social science literature on work and family life, and assesses both private sector policy and public policy. Professor Kochan explains the report's conclusions. He says, "There is a serious institutional lag at present between private sector policies and labor laws developed in the 1930s and the problems facing working families today. If we want to integrate work and family life in the twenty-first century, it will require a well-informed collaborative effort on the part of all the key actors that share interests and responsibilities in these issues." The MIT Workplace Center is applying this stakeholder approach to its research and its public education efforts in an attempt to move away from single-party, piecemeal solutions and towards multi-sector involvement in systemic change.

Our research agenda is based on the study of work-family issues in the greater Boston metropolitan region. This area includes a multi-state labor market that crosses the state lines of Massachusetts into New Hampshire and Rhode Island. Using a regional approach is one way of concretizing our view that work-family problems do not fall neatly into preconceived categories with clear boundaries. Rather, we study how problems at work spill over into home, and even into the community, and how family and community issues may affect the operation of the workplace.

Our research agenda is based on the study of work-family issues in the greater Boston metropolitan region. This area includes a multi-state labor market that crosses the state lines of Massachusetts into New Hampshire and Rhode Island.

We have chosen three industries that are critical to the functioning of this regional economy: health care, high tech, and legal services. In each industry, we begin by collecting baseline data on the scope of products and/or services, the size and demographic composition of the workforce, recent trends affecting the structure, organization, and vitality of companies in the industry, and information on work-family policies and practices.

In the Center's first year, we have developed a number of projects in the health care industry. Health care is the leading employer in Massachusetts, with over 450,000 workers in a wide variety of professional, para-

(Continued on next page)

Integrating Work and Family Life: Research at the Workplace Center

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professional, and low-wage service occupations. In the summer and fall of 2001, we interviewed over 40 leaders in the industry to learn about pressing workforce issues. Interviewees reflected on their experiences with the current health care system as employers, union leaders, public officials, leaders of community organizations, professional associations, and others. We convened this group in a stakeholder dialogue soliciting their views and concerns to help shape our key research questions. We found that although many participants described problems with long/inflexible work hours, staffing shortages, high levels of stress, and degraded working conditions, they did not identify these issues as connected to work-family dilemmas. Mona Harrington explains the relevance of this disconnect to our research/action agenda, "The American idea that work-family is a problem for individuals to solve as best they can remains so strong that it prevails even in an industry like health care, operating 24/7 with a predominantly female workforce – nurses, technicians, and increasingly physicians – many of whom have family responsibilities. Challenging that idea is the starting point for our projects."

The exchange and multiplicity of perspectives in this stakeholder meeting laid the foundation for our current research. For example, one participant highlighted severe problems produced by long hours among medical residents. Sloan doctoral candidate Kate Kellogg and her advisor Lotte Bailyn, have begun a study in two acute care hospitals to look at the impact of new policies to reduce residents' work hours on both the quality of patient care and the family lives of health care workers. Kellogg has begun interviews and work observations among surgical residents, and Bailyn is exploring work organization and family life among nurses and certified nursing assistants who also care for surgical patients.

Another project is focused on innovative approaches to providing health care in long-term care facilities. Ann Bookman and Mona Harrington are collaborating on a study of professional health care employees who are organized in teams to provide extended and palliative care to elderly and/or terminally ill patients. They are examining the way the team model of work organization affects the quality of patient care, relations with other nursing home workers, and opportunities for work-family integration. They are also interviewing the family members of patients, a group who face their own set of work-family issues. These family members are caught in a bind – more and more health care is being pushed down into the home to save costs at the same time that most adults are working, unable to be home to care for their families. The aim is to develop a cross-occupational picture of the extended care workforce, and to document the workings of a care system that links paid caregivers with unpaid caregivers, blurring the work-family "boundary."

Sloan doctoral candidate, Forrest Briscoe, guided by his advisor Thomas Kochan, is studying physicians in a health maintenance organization (HMO). Briscoe is interested in how the dramatic restructuring of the health care industry and the increasing number of dual-career families are affecting the pattern of physicians' careers. Combining survey data and qualitative interviews, Briscoe has hypothesized that while large medical organizations may have diminished some aspects of physician autonomy and control, they also are providing new career paths in health care management, as well as more flexibility in work hours and accommodation of family needs.

Several Sloan School faculty members are conducting research in conjunction with the MIT Workplace Center. Professor Diane Burton is studying the performance of high tech start-up firms, focusing on the relationships between a company's employment practices – such as hiring, training, promotion, and work-life policies – and their business strategy. Professor Roberto Fernandez is surveying new nurses to better understand the place of non-pecuniary rewards, such as flexible hours, in their job choices and career paths. Professor John Carroll is convening a stakeholder dialogue on preventing medical error and increasing accountability in health care. He is also beginning a project with operating room anesthesiologists to explore strategies for improving team communication in this high stress occupation, strategies that could enhance life on the job and at home.

Although the MIT Workplace Center is still developing its agenda, we have learned much in our first year. We hope that others on the MIT faculty who are working in related areas will share their findings with us, and expand the list of questions we can take into the field. We believe that researchers laboring inside the academy are important stakeholders in the evolving effort to create a society that values paid work, family care, and community involvement. Please join us in any way you can.✣

[Ann Bookman can be reached at abookman@mit.edu]

Advanced Technologies Improve Research and Teaching at MIT

M. S. Vijay Kumar

[Director of Academic Computing Vijay Kumar tells how innovative technologies at the Institute can assist faculty.]

"It has been 30 years since MIT last saw such a groundswell of educational innovation and it's beginning to transform the classroom experience."

This headline, from an article in the May 2002 edition of *Technology Review* about the unprecedented nature of MIT's engagement with technology-enabled educational transformation, is indeed supported by the initiatives that have been launched over the past couple of years.

In recent months, more progress and new milestones have been achieved in these areas:

- New educational innovation projects that explore new modalities for teaching and learning, such as case-based learning, mechanisms for rich and immediate feedback, Web-enabled laboratories, and collaborative design have been selected for support through the i-campus and d'Arbeoff funds <http://web.mit.edu/mitcet>.
- The next phase of OpenCourseWare (OCW) is underway with the intent of producing approximately 50 courses by September.
- Efforts with implications for major programmatic and curriculum changes, such as those in the Departments of Aeronautics and Astronautics, Brain and Cognitive Sciences, and Mechanical Engineering, have advanced.

The success of these educational experiments and projects requires an organizational and technical infrastructure that will support their large scale and sustainable implementation, including their integration with the institutional infrastructure.

The recently configured AMPS (Academic Media Production Services), along with the development of the Stellar platform for learning management with its foundational project OKI, represent key initiatives in this regard.

AMPS

Academic Media Production Services (AMPS) <http://web.mit.edu/amps> is an organization that delivers an array of professional, high quality, cost-effective technology services to support the production and delivery of educational materials. AMPS staff support faculty and academic programs in a variety of ways: from building course Websites and on-line educational tools to help in delivering video-based instruction for local and distance audiences. AMPS services include the design and operation of facilities such as the Linc in Building 9, Building 1-390, and Building 8-404, for supporting diverse needs of broadcast instruction and small-group research interactions.

AMPS staff with competencies in video production, digital media production and delivery, education design and integration are available to not only help faculty find the right multimedia technology solutions for their courses as they explore new pedagogical models, but also execute a well-planned and sustainable educational project.

Besides the support to faculty initiatives being provided through Stellar and OCW, AMPS portfolio of projects and clients <http://web.mit.edu/amps/projects/portfolio.html> includes SMA, MUST, i-Campus, and d'Arbeloff-supported educational innovation projects, the Museum Loan Network, as well as some external projects through CAES.

The organizational capacity for supporting educational technology being created through AMPS is complemented by the robust technical substrate being developed through Stellar and the Open Knowledge Initiative (OKI).

Stellar

The Stellar development project <http://stellar.mit.edu/> grew out of the needs of MIT's educational programs as part of the strategic Singapore MIT Alliance (SMA), depending in part on supplemental Web-based learning materials that are securely, conveniently, and reliably available. As the SMA program demands grew and diversified, the effort to support and sustain this critical application multiplied. It quickly became apparent that a reliable system that was also easy for faculty and technology support staff to use, maintain, and support, was needed.

Stellar was, however, envisioned from the start as a foundation upon which not just SMA, but departments, labs, and centers across the Institute could build. This required a learning environment that fully endorsed current software standards, ran on MIT standard hardware, and leveraged MIT enterprise systems.

Stellar has been adopted as the core of the SMA program's Web-based course delivery system. It is also used by selected departments and courses who participated in the early stage pilot rollout.

Stellar features support for a range of commonly needed content management and course administration tasks, in addition to enabling teaching and learning through a range of educational services. Stellar's functionalities include:

1. Content Management Course materials prepared using popular authoring tools, such as Microsoft Word, PowerPoint, Dreamweaver, PDF authoring tools, etc., can be uploaded. These materials are then available to students directly, in the format in which they were prepared. Streaming video and other advanced multimedia materials can also be used.

2. Course Calendar Materials are also available in a calendar listing, so that students know how the materials have been scheduled.

3. Announcements Faculty can author and schedule announcements. Current announcements are also listed on the course home page.

4. Threaded Discussion Board Allows faculty to set up forums within a class for different purposes, and for faculty and

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Advanced Technologies Improve Research/Teaching

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students to post messages and communicate. Documents can also be attached as a way of exchanging materials during the dialog.

Among the advantages of Stellar are:

• The ability to make library materials an integral part of class work, by linking E-Reserves directly into Stellar.

• Access to the Registrar's information about classes and students.

• Ability to use an existing Website and integrate Stellar as tools *or* integrate existing pieces from any Website.

As an operational system Stellar has provisions in place for backups, disaster planning, continued enhancements, and support. To access MIT Stellar, all you need is a Web browser. Current versions of Netscape and Microsoft Internet Explorer are supported.

Stellar is also being considered as an enabling infrastructure for educational technology projects as part of the Cambridge MIT Institute (CMI), as well as those supported by i-Campus and the d'Arbeloff initiatives. Stellar functionality is also available to courses being published on the Web as part of OpenCourseWare.

This fall, Stellar support will be available to faculty through the combined efforts of the Academic Computing Support Team (IS) and AMPS. To request Stellar for your course, fill in the Stellar Course Request and Information form at <http://stellar.mit.edu/contact/index.html>.

Stellar's Future – OKI

Stellar is on a path to converge with the design specifications under development by the Open Knowledge Initiative (OKI) <http://web.mit.edu/oki>.

OKI is an MIT-led collaboration of major universities to develop a layered, component architecture, for educational applications and learning systems. Funded by the Mellon Foundation for the first two years, other key partner institutions include Dartmouth College, Harvard University, North Carolina State University, the University of Michigan, the University of Pennsylvania, the University of Wisconsin-Madison, the University of Washington, and the University of Cambridge.

A practical initiative driven by the need to support faculty who are trying to do sophisticated and creative work with online education, and who have become increasingly frustrated with available tools and products, OKI's focus on interoperability and an open layered architecture is specifically designed to support evolving and flexible teaching and learning requirements. The design and deliverables of the project have been primarily influenced by pedagogical considerations.

OKI is defining an architecture that precisely specifies how the components of a learning technology environment communicate with each other and with other campus systems. By clearly defining points of interoperability, the architecture allows the components of a complex learning environment to be developed and updated independently of each other.

This leads to a number of important benefits:

• Learning technologies appropriate for a range of teaching and learning requirements can be integrated together into a common environment. (The needs of the Physics Department are not those of the Economics Department, and tools that work well for new users may not be adequate for seasoned users.)

• Learning technology and content can be more easily shared among schools and departments. This provides a catalyst for cooperative and commercial development.

• There is a lower long-term cost of ownership because single components can be replaced or upgraded without requiring all other components to be modified.

• Modularity makes learning technology more stable, more reliable, and able to grow with increased usage. OKI is based on technologies that have proven to be scalable and dependable in large-scale enterprise computing environments.

The interface methods defined by OKI support the ongoing integration of three general categories of software:

• Learning applications such as course management systems

• Administrative systems such as student administration systems, and

• Common infrastructure services such as authentication and authorization.

Once this architecture is fully adopted by the education market, new components may be plugged into the learning infrastructure using OKI's tightly defined and standardized application programming interfaces (APIs). This will allow us to more easily take advantage of new technology and new learning components as they become available. It will also allow components to be updated individually without destabilizing the overall environment.

The OKI architecture enables the sharing of learning content and software applications among schools and departments. The common architecture and common interfaces will allow schools to more easily implement components developed by other organizations, as long as all parties are conforming to the architecture. To demonstrate this, OKI will make the learning management environments of MIT, Stanford, and the University of Michigan available as open source code.

Finally, selected Common Services defined by OKI are being integrated into Stellar, a significant first step toward leveraging the pioneering work of OKI. As this integration progresses, future versions of Stellar will fully implement the OKI architecture, making Stellar MIT's OKI implementation. A consistent theme in the evaluations of Stellar has been its robustness as a platform to meet MIT's educational goals, as required by OCW and other educational technology initiatives.✣

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From The Libraries

Digital Repository for MIT Research Goes Live This Fall

Margret Branschofsky and Ruth K. Seidman

[DSpace Faculty Liaison Margret Branschofsky and MIT Libraries Communication Coordinator Ruth K. Seidman discuss online posting and retrieval of documents.]

Over the spring and summer of 2002, DSpace, the digital repository of MIT research developed by the MIT Libraries in collaboration with the Hewlett-Packard Company (*MIT Faculty Newsletter*, April/May 2000, p. 18), underwent a testing period to gain an understanding of how contributors use the system and what features they find most useful. The system is scheduled to go live early in the fall.

Content for DSpace is provided through MIT units such as academic departments or laboratories that form DSpace Communities. The Early Adopters, the four participating Communities in the test phase, are the Sloan School of Management; the Department of Ocean Engineering; the Center for Technology, Policy and Industrial Development; and the Laboratory for Information and Decision Systems. Selected to reflect different types of MIT organizational units representing a variety of user needs, the Early Adopters submitted digital items to collections within their own "Communities" and provided feedback to the DSpace team. In addition, DSpace has loaded a collection of out-of-print books provided by the MIT Press.

Members of the faculty serve on the DSpace Advisory Board, providing guidance from the perspective of MIT users of DSpace, both as contributors of content and as end-users of the system. Several of the design elements in the system came directly from advice provided by this group. MIT Libraries are also administering a survey of MIT faculty in order to learn about their perceptions and anticipated use of DSpace. The survey results will further contribute to DSpace design plans.

Benefits of Participation

DSpace provides long-term physical storage and management of digital items in a secure, professionally managed repository including standard operating procedures such as backup, mirroring, refreshing media, and disaster recovery. It has long been the role of academic libraries to preserve the print record of scholarly work. With DSpace, MIT Libraries is making a commitment to preserve the digital record of scholarly work over a long period of time. Techniques for assuring long-term preservation of digital files are still in a stage of experimentation and discovery, but MIT Libraries will be monitoring developments in this field and will take appropriate actions to ensure the safety of the collections in DSpace.

Visibility for research results is another benefit of DSpace. Because ultimately this will be a repository containing content from all of MIT, it will have more visibility than individual Websites. Users will consider it an online place to find MIT research information. The Digital Library of MIT Theses is already receiving significant amounts of access from users worldwide. In future releases end users will be able to establish subscriptions that will result in e-mail notification when items fitting their interest profiles are added to DSpace. Communities will also be able to target discussion lists and news groups in their field to receive e-mail notification of new items.

Searching capabilities for DSpace provide targeted retrieval. DSpace has powerful search capabilities that allow users to retrieve deposited material in a variety of ways, making it easier to find the information being sought.

Participation relieves labs and centers of the time-consuming work associated with making material available on the Web as well as in print. The system, while professionally managed and staffed, allows some customization of look and feel for communities and collections. It also provides flexible submission processes that can be adapted to workflows in a particular community.

Finally, DSpace allows distribution of formats such as data sets, images, and audio and video files, not easily handled through traditional publications. In the case of images, many journals require a higher page charge for pages containing images. As a consequence authors tend to limit the number of images they submit for publication. But when an author stores an image in DSpace, a persistent URL is assigned to that file; the author can then use that URL as a citation in his or her published works, referring people to the images on DSpace.

Seeking Solutions to Scholarly Communications Issues

The scholarly community is watching with interest DSpace and other efforts to create digital collections capturing the intellectual output of universities. A newly issued report from The Scholarly Publishing and Academic Resources Coalition (SPARC), "The Case for Institutional Repositories: A SPARC Position Paper" (available at http://www.arl.org/sparc) looks at these repositories from two perspectives. First, they are seen as an extension of academic institutions' responsibility as generators of primary research seeking to preserve and leverage their constituents' intellectual assets. Second, such efforts are considered as an important component in the evolving structure of scholarly communication.

The Executive Summary states: "Institutional repositories can provide an immediate and valuable complement to the existing scholarly publishing model, while stimulating innovation in a new disaggregated publishing structure that will evolve and improve over time." Such

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repositories provide a critical component in reforming today's system of scholarly communication by expanding access to research and reasserting the academy's control over scholarship.

Next Steps and Future Directions

Now that the testing phase has been completed, additional MIT communities are joining DSpace as content providers. Faculty members are encouraged to contact *dspace-info@mit.edu* to learn more about participation. Beyond the Institute, in response to considerable interest from peer institutions, the MIT Libraries are exploring the best ways to make DSpace available to other universities on a federated model and also to make the system widely available for other institutions to use under an Open Source license.

MacKenzie Smith, DSpace project director and MIT Libraries associate director for technology, has commented: "The DSpace system, both in what it's trying to accomplish and in how it's being deployed at MIT, is a truly groundbreaking effort that has the potential to influence scholarly communication in ways that we can hardly imagine right now. Having a platform like this will allow so much to happen: new and innovative research in federating distributed repositories and digital preservation, new models for scholarly communication, and new ways to support educational technology initiatives, to name just a few. And most importantly, DSpace will allow libraries to continue to fulfill their mission to capture, manage, preserve, and make available the output of scholarship in the digital era."✣

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Using Journals and Databases Online: What's Legal and What's Not

Ellen Finnie Duranceau

[MIT Libraries Digital Resources Acquisition Librarian Ellen Finnie Duranceau discusses potential violations of license agreements.]

What do these situations have in common?

• A student visiting MIT for a summer program tries to satisfy his thirst for knowledge by downloading hundreds of papers from a society publisher's Website using a robot;

• A faculty member writes code that will search for particular terms in the full text of a newspaper and automatically download all the content resulting from the search;

• A visiting scholar downloads and prints entire issues from many social science ejournals over a two-day period;

• A graduate student beginning his dissertation research systematically downloads a list of thousands of papers relating to his broad topic in a citation database.

What these activities share is that they fall outside the bounds of the use contracted for when the MIT Libraries signed a license to gain campus-wide access to the databases or ejournals involved. These databases and ejournals are listed in the Libraries' access tool Vera <http://libraries.mit.edu/vera>, and include products like Lexis-Nexis Academic Universe <http://libraries.mit.edu/get/lexis-nexis> and SciFinder Scholar <http://libraries.mit.edu/guides/cheatsheets/scifinder/> as well as ejournals like those found at the JSTOR site <http://libraries.mit.edu/get/jstor>, or at the American Institute of Physics' site <http://www.aip.org/ojs/entry.html>.

To offer these databases and ejournals here at MIT, we must sign a license agreement that specifies terms of use; although we try to negotiate licenses that cover normal scholarly activities and that approximate the concept of "Fair Use" under U.S. copyright law, the licenses' terms trump copyright. The terms of the license, not copyright law, determine how these products may be used. While terms of use may vary depending on our negotiation, in general they specify that electronic journals and databases be only for individual, noncommercial use without systematically downloading, distributing, or retaining substantial portions of information. The use of software such as scripts, agents, or robots, is implicitly prohibited.

It is important to be aware of these terms, since misuse jeopardizes access to the content for the entire campus, and could result in legal action. Most information providers now have controls on their servers that monitor unusual use, and some have provisions that automatically shut access down when such misuse occurs.

What recourse, then, do you have if your research project requires searching or downloading that falls outside the bounds of what is allowed under the license terms? If this is the case, you can contact the Libraries' licensing specialist, Ellen Duranceau (efinnie@mit.edu; x3-7562) who can advise you about your options. While we cannot guarantee that every request will end in a positive result, we have had success acting as a liaison with information providers to achieve several different solutions to such research needs.

So far, we have been able to manage every case of misuse, including those summarized above, so that any suspension of access to MIT was only temporary and we have been able to find alternative paths for innovative fulltext research to take place. Our ability to continue to do so depends on the responsible use of these products by all faculty, students, and researchers, and we appreciate your cooperation.✣

[Ellen Finnie Duranceau can be reached at efinnie@mit.edu]

While you were away . . .

Janet Snover

[Special Assistant to the Executive Vice President Janet Snover highlights administrative news items that were announced over the summer, and where you can get more information about them.]

• Two longstanding MIT programs for professional education, the Professional Institute and the Advanced Study Program, have moved to the School of Engineering. For more than 50 years, the Professional Institute has offered week-long summer programs taught by MIT faculty. The Advanced Study Program has been bringing professionals to campus for part-time or full-time study for almost 40 years. (*Tech Talk* 7/17/02)

• The Center for Transportation Studies has changed its name to the Center for Transportation and Logistics. The name change reflects the Center's efforts to focus more on logistics and supply chain management. Its mailing address, all phone numbers, and e-mail addresses remain the same, but the URL for its Website has been changed to <http://web.mit.edu/ctl>.
(*Tech Talk* 7/17/02)

• In late spring, the MIT president's residence was named Gray House in recognition of Paul and Priscilla Gray's outstanding contributions as leaders of the Institute community during more than four decades, including their years in residence at the House as President and First Lady of MIT from 1980 to 1990.

• Residential Life and Student Life Programs was divided into two departments in mid-July. They are the Department of Student Life Programs and the Department of Housing. Associate Dean Barbara A. Baker will continue to head Student Life Programs and Karen Nilsson will lead the Department of Housing.
(*Tech Talk* 7/17/02)

• A new online Acronym and Abbreviation dictionary has been compiled to assist the MIT community in deciphering the "alphabet soup" of shorthand terms that often are used here. The dictionary is at <http://web.mit.edu/acronym> and it also is accessible from the "about MIT" category on the MIT home page.

• The MIT Travel Office has negotiated agreements with Alitalia Airlines and Swiss Air for discounts on MIT business travel. On Alitalia, MIT flyers can get up to 60 percent off the published fares on some flights to European destinations. On Swiss Air, there are 24 percent discounts on unrestricted business and economy class fares and 17 percent discounts on restricted economy fares, excluding sale fare types. The discounted fares are available only at Navigant International Boston, OT&T Travel Management, and the Travel Collaborative. (For details, see the Travel Office Website at <http://web.mit.edu/cao/www/travel.htm>.)

• Quantum Books and the MIT Press Bookstore now accept TechCASH, a feature of the MIT ID card that allows students and employees to use their card to pay for items like dining hall meals, food from LaVerde's, and CopyTech services. Many students may want to purchase their textbooks from Quantum to avoid paying cash or using a credit card. (The Coop has elected not to participate in TechCASH but will continue to sell textbooks for cash or credit.) Questions about TechCASH may be e-mailed to <Techcash@mit.edu>.

• MIT has introduced two new food service contractors to the campus. Sodexho operates Lobdell, Walker, the Dome Café, Building 4 Café, Bio Café, and East Side Café. (In the fall, they also will run the new café in Lobby 7 and the juice bar in the Zesiger Sports and Fitness Center.) Bon Appetit will operate residential locations in Baker House, Next House, and Simmons Hall, as well as the convenience store in MacGregor. MIT Campus Dining also is bringing two new independent merchants to the Student Center, Alpine Bagels and Arrow St. Crepes.

• For this academic year, the fee for a regular commuter parking pass increased to $466 from $420 last year. Information about parking, MIT's 50 percent MBTA subsidy program, shuttles, and alternative transportation choices are available online at <http://web.mit.edu/parking>.✣

[Janet Snover can be reached at jsnover@mit.edu]

MIT WebMail: A Way to Get Your E-Mail on the Go

Jag Patel

[Now faculty can access their MIT e-mail account from any computer with a Web browser and an internet connection, explains Senior IT Consultant Jag Patel.]

In Spring 2002, Information Systems (IS) announced support for WebMail, which allows MIT users to access e-mail from a Web browser. Since then, close to 9,000 MIT Community members have used it, including over 200 members of the MIT faculty. WebMail is available from <http://web.mit.edu/webmail/>, or log in directly at <http://webmail.mit.edu>.

WebMail is a convenient and secure way to access e-mail using almost any Web browser from just about anywhere in the world. IS introduced the service to meet the demand for ways to access MIT e-mail remotely, where remotely might be a research lab on-campus, or another country.

The MIT WebMail home page summarizes browser requirements and contains links to additional information, including instructions for use. IS continues to work on the program and will install updates periodically and post announcements about changes, problems and outages on the WebMail page. Help can be obtained and feedback provided by sending e-mail to *webmail@mit.edu*.

How WebMail Works

Using a recent version of a browser such as Netscape or Internet Explorer on a computer connected to the Internet, members of the MIT community should be able to get to MIT WebMail, no matter where they are. The only requirements are a browser that supports SSL encryption, and has JavaScript enabled. An MIT CA certificate also will need to be installed on the computer; recent browsers will prompt the user for the installation. The MIT personal certificate is not necessary to access WebMail.

At this time WebMail works only with e-mail accounts ending with @mit.edu. It does not work with other MIT mail domains, such as @ai.mit.edu, or with e-mail forwarding accounts such as @sloan.mit.edu.

When the user logs in, WebMail displays a list of messages in the Inbox. Messages can be read, replied to, forwarded, deleted, or selected and marked in various ways. The user can send new messages, create new folders and search the Inbox. When the user logs out from WebMail, messages and folders that have not been deleted will be available for downloading when the user next accesses e-mail in the usual way.

Benefits of Using WebMail

WebMail does not require users to install any software on a machine to check e-mail – only an internet-connected browser is needed. WebMail allows users to manipulate messages directly on the MIT post office servers, allowing users to leave mail there until they are deleted and purged, or downloaded to a local machine. WebMail also allows users to take advantage of a 100 MB mail quota, which is considerably higher than accounts offered by public webmail services, such as Yahoo or Hotmail.

WebMail does have some limitations: it is not intended for long-term, archival handling of e-mail, because of enforced quota limits for e-mail accounts on the post office server. Currently, WebMail does not provide an easy way to move messages from the post office server to a local computer or Athena home directory. Other features typical of desktop e-mail clients – such as keeping local copies of messages sent, providing an address book, filters, and long-term archiving – are unavailable.

IS Support

"Email Scenarios and Recommended Solutions" <http://web.mit.edu/is/help/email/scenarios.html> provides information about e-mail clients and protocols supported by IS that can help users take full advantage of WebMail. IS provides support for WebMail through the Computing Help Desk and online documentation, and it is covered in Quick Start classes about e-mail.

[Jag Patel can be reached at jag@mit.edu]

Now You Can View Your Institute Benefits and Update Your Personal Info Online

Over the summer, a new Web-based tool called employee self-service (ESS) was released to the MIT community. It allows faculty and staff who work on campus to view their MIT benefits and to update some of their employee information online, and is available at <http://web.mit.edu/sapwebss>.

Information that can be updated includes primary and alternate MIT office addresses; office telephone number, MIT pager and mobile phone numbers; e-mail address; and home information. Faculty and staff also can view and verify their name, department, and position title. In addition, they can view their health and welfare benefits enrollment, including level of coverage, their dependent information, and plan costs throughout the year.

These new services are enhancements to the Web application used successfully during Benefits Open Enrollment last November.

"Based on the recommendations of several teams working on the HR-Payroll Project, we decided to provide ESS so community members will have a more direct and a faster way to review and update information about themselves," Vice President for Human Resources Laura Avakian said. "For example, if an employee moves to a different MIT room number, he or she can update that information using ESS, and by the following business day, the MIT online directory will reflect the room change," she said.

To ensure confidentiality, an up-to-date MIT personal certificate is required to use ESS. Personal certificates are set to expire periodically, and those obtained in the past year were valid until July 31. Renewal is not automatic. To obtain a new certificate, go to <http://web.mit.edu/is/help/cert> and click on "Get MIT Personal Certificate." For questions or problems with certificates, contact the Business Liaison Team (BLT) in Information Systems, Monday through Friday, 8 a.m. to 6 p.m. Their e-mail address is *business-help@mit.edu*, and their phone number is x2-1177.

The availability of ESS also means that there is a revised process for updating the faculty and staff telephone *Directory* this year. Faculty can either update any *Directory* information about themselves that has changed since the last phonebook was published or have the telephone *Directory* coordinator in their department submit it (via paper) on their behalf. (Changes made in ESS after October 11 will update the online directory but not the printed version.)

To use ESS (either to update information for the telephone *Directory* or to view health and welfare benefits choices), go to <http://web.mit.edu/sapwebss>.

It's important to note that changes reported via ESS will update records only in Human Resources and Payroll. At this point, employees will still need to notify offices such as the Credit Union and MIT Medical if their contact information changes.✣

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Tennis Anyone? Would You Believe Golf?

The Department of Athletics, Physical Education and Recreation is offering a new program for *faculty only*. Lessons for novices will be given in tennis and golf. Please conact Lynn Couturier *(couturie@mit.edu)* for more information.

Thanks Faculty, from the Alumni Association

Lou Alexander

[Alumni Affairs Officer Lou Alexander acknowledges faculty contributions.]

The Association of Alumni and Alumnae of MIT would like to publicly thank the members of the MIT faculty and senior administration who so generously gave of their time to meet with alumni groups around the world this past year. Because ours is a population ever thirsty for knowledge, ongoing contact with you, the faculty, is the single most important service we can offer them. For a complete list of faculty who made presentations in cities across the United States, Canada, Asia, the Middle East, and Europe, see the online version of the *Faculty Newsletter* at <http://web.mit.edu/fnl>.✣

[Lou Alexander can be reached at lalexan@mit.edu]

Graduate Student Enrollment and MIT's Research Agenda

Sanith Wijesinghe

[Graduate Student Council (GSC) President Sanith Wijesinghe offers suggestions for maintaining U.S. preeminence in science and technology.]

In keeping with the spirit of this edition of the *Faculty Newsletter*, I'd like to direct your attention to two points cited in the "Science and Engineering Indicators 2002" report released by the National Science Board that could have possible long-term implications for graduate recruitment and enrollment and subsequently MIT's research agenda:

1) The United States may face increased international competition for highly educated personnel. Furthermore, its relative attractiveness may erode as living standards rise in developing countries and as other industrialized nations intensify their international recruitment efforts.

2) U.S. preeminence in science and technology may erode as competing centers of excellence are established elsewhere. Foreign graduates may find returning home more attractive than staying in the United States after their training, and industry may locate increasingly sophisticated functions overseas.

Let alone developing remedial actions to address issues of competitiveness, there currently exists no Institute-wide infrastructure to track graduate enrollment statistics. Common sense business practice dictates MIT must position itself to assess long-term trends of its most valuable resource – its students. While implications of global economic standings could seem rather far-fetched in planning for enrollment, MIT's graduate research student population is currently close to 40 percent international. Both of the above points therefore have significant coupling effects on MIT's ability to sustain its research agenda. As a minimum, a systematic review of graduate recruitment and retention strategies must be developed and is indeed long overdue.

Moreover, the current climate of heightened security concerns further reinforces the above points for U.S. research institutions. Blanket policies that adversely affect visa application procedures through accessibility of research funds for international graduate students has been a topic of considerable discussion amongst students and faculty alike. The recently released report "In the Public Interest" authored by MIT's ad hoc faculty committee on access to and disclosure of scientific information, has received wide acclaim and is a positive step towards clearly articulating the adverse affect of such policies. MIT must continue its leadership in this regard by engaging universities across the nation to further develop the case for academic openness and collaboration. The future of the nation's preeminence in science and technology relies on it.

In closing, I'd like to bring to your attention our graduate community discussion forum at <http://gsn.mit.edu> and encourage your feedback and comments on these issues here.

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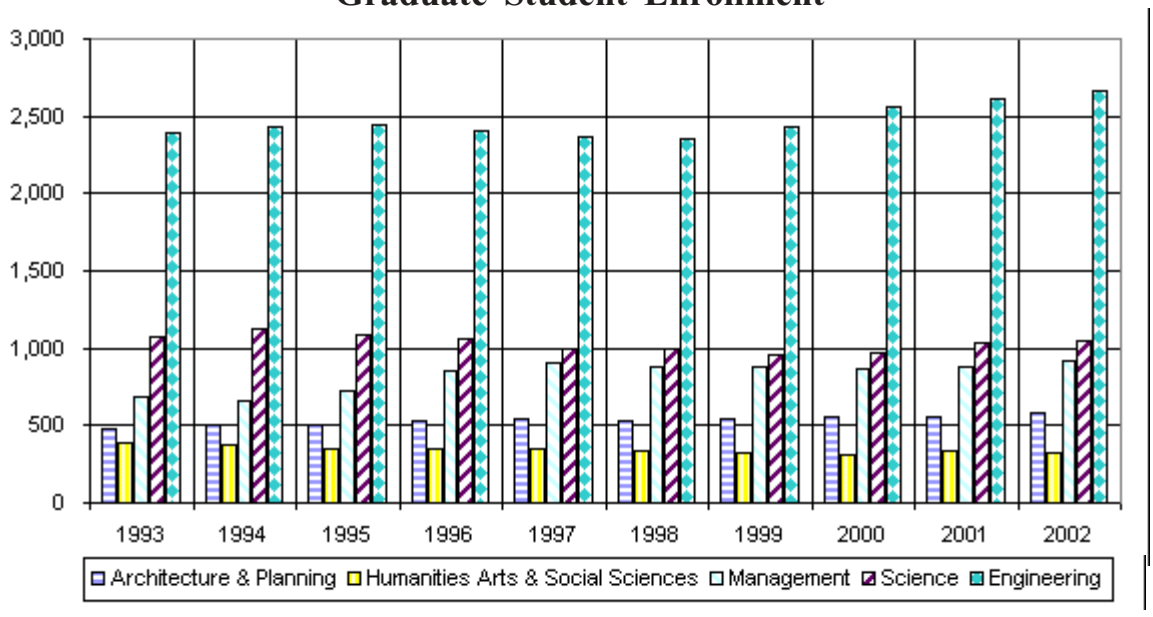
M.I.T. Numbers

Graduate Student Enrollment



Source: Office of the Provost

M.I.T. Numbers

Research Funding

(thousands of dollars)

	1993	1998	1999	2000	2001	2002
FEDERAL						
DHHS	64,882	58,938	58,246	65,905	69,539	74,806
DOE	57,325	70,281	63,138	57,000	57,780	59,658
DOD	66,769	64,776	65,718	65,686	60,971	60,117
NSF	38,008	36,264	35,352	35,669	37,520	44,878
NASA	32,324	30,227	27,301	22,734	18,592	25,119
Other	8,899	9,115	7,409	6,753	6,777	11,562
Subtotal	**268,207**	**269,601**	**257,164**	**253,747**	**251,179**	**276,140**
NON-FEDERAL						
Industry	62,068	74,062	74,325	73,609	92,036	99,966
Nonprofit	25,593	36,197	42,214	50,970	55,588	63,638
Other	5,487	6,495	2,344	5,662	8,620	8,145
Subtotal	**93,148**	**116,754**	**118,883**	**130,241**	**156,244**	**171,749**
TOTAL	**361,355**	**386,355**	**376,047**	**383,988**	**407,423**	**447,889**

Source: Office of Sponsored Programs