**University of Michigan**

# President's Information Revolution Commission Report

**April 2001**

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# Executive Summary

## *The University in a Changing Information Environment*

Never has the need been more pressing for the University of Michigan to examine its relationship to information and communication technologies. The information revolution that is radically altering our whole world at an ever-accelerating pace touches every aspect of university life. Information — the foundation of knowledge — is at the very heart of a university's mission: the generation, preservation, dissemination, and application of knowledge. If we do not adapt rapidly and continuously to this revolution, we run the risk of failing to sustain our mission in the new age. Fortunately, we have the wherewithal not only to adapt but, in the tradition of a great public university, to help shape the revolution itself.

The future holds much in store: broad access to massive datasets, such as those associated with the human genome project, global information systems, or astronomical surveys; emergence of large-scale multimedia communication; convergence of the Internet, broadcasting, and telecommunications; extensive wireless, mobile, embedded, and wearable computing; smart houses, smart buildings, smart transportation — the list could go on.

At the University of Michigan, Internet usage is doubling annually, and the percentage of students who use e-mail regularly has grown from seventeen percent to ninety-seven percent in just seven years. As the potential for communication increases, so do concerns about security and privacy. Thorny legal and ethical issues are arising as well. During the past year, the University administration has faced decisions about blocking access to the music-sharing website Napster, and faculty have wrestled with digital copyright issues. At the same time, information has become an increasingly valuable commodity, and new opportunities have arisen for the University to participate in the "knowledge economy."

The President's Information Revolution Commission was appointed to consider how we as an institution can best capitalize on the opportunities and address the challenges arising in this ever-evolving information environment. Rather than simply assessing information and communication technology needs, as many other universities have done, this commission and its subcommissions took a broader, deeper look, surveying existing strengths and weaknesses not only in the infrastructure, but also in our uses of the technology and our understanding of its impact on our lives. Members explored what it means to be educated — and to be an educator — in the 21st Century, and how the basic missions of a university must change in response.

What emerged was a sense that the University of Michigan is at a point of precarious balance. With adequate investment in human capital and physical infrastructure, strong leadership, and coordinated, campus-wide involvement, the University can take the lead in redefining higher education in light of the information revolution. Without such commitments, our longstanding position of strength — not only in the application of information technology, but also in virtually all areas of research, scholarship, and teaching — will erode.

## *An "Ecology of Experimentation"*

The myriad changes brought about by the information revolution have been swift and unpredictable. Because we cannot anticipate changes still to come, our best strategy is a flexible one, in which experimentation is encouraged, experiences are shared, and success and failure are viewed as equal partners in the process. The key is to experiment in a systematic fashion, coordinating and exchanging information across the institution, and in the process transforming the University into a living laboratory. From this "ecology of experimentation," new information and communication technologies — and perhaps whole new disciplines — will emerge, and insights will be gained into better ways of creating and sustaining the educated person. In this way, we not only will participate in the revolution, but we also will help shape it.

The commission identified a number of areas where the University can build on existing strengths and achieve new levels of excellence:

- Developing, deploying and exploring innovative uses of technology-mediated research environments — "knowledge networks"
- Expanding the definition of an educated person in the information age
- Integrating information and communication technologies throughout the University and across the curriculum
- Extending learning opportunities to communities beyond the traditional boundaries of the University

### Knowledge Networks

Research and scholarship are increasingly interdisciplinary, collaborative efforts. The Internet and new information and communication technologies are enhancing — and transforming — research and scholarship, enabling users scattered throughout the world to share facilities, instruments, immense collections of multimedia information, and tools for analysis and synthesis. These technology-mediated environments, often called *collaboratories* or *knowledge networks*, not only allow scholars and scientists to work together more effectively, across distance and discipline, but also offer whole new approaches to investigating and analyzing concepts and phenomena.

Just as the telescope and microscope revolutionized science by opening up realms that had been hidden from our view, new tools and technologies such as high performance computing are revealing previously undetected patterns and correlations in massive sets of data and text, expanding our horizons of inquiry and knowledge. The excitement that today's astronomers feel when they discover an unexpected pattern in a vast data set is akin to what Galileo must have felt when he turned his primitive telescope on Jupiter and first saw the planet's moons. In the humanities, linguistics scholars feel similarly about the ability to analyze millions of instances of human language as it is used day to day.

Over the past decade, the University of Michigan has played a key role in designing, developing, and applying knowledge networks. The University should continue to pioneer by further developing knowledge networking technology, exploring innovative uses for it, and studying its impact on the way we work and learn.

In addition to building on existing collaboratory projects, the University should support a few carefully selected knowledge network experiments that capitalize on the University's special resources and intellectual assets and are likely to have high impact across all research fields.

## "Educated" in Information

Sudden and dramatic as it seems, the information revolution is more an information *evolution* that has taken place over the past half-century. As such, it has a history. It has affected and been affected by social, cultural, economic, political, legal, and psychological issues. We must address these issues as an institution and make sure that our students understand their implications, not only in the abstract, but also in relation to their everyday lives. University of Michigan graduates need to be able to "swim" in the new, information-intensive environment, wisely managing and evaluating the information that bombards them daily. They need to be wise, masterful, and responsible readers, interpreters, and producers of information that is mediated in new ways by technology. They need to be able to develop knowledge from information, through discovery, analysis, and synthesis, utilizing new technologies while also appreciating their mediating effects. They need to understand how information and communication technology is changing society and the world, and how they can help direct that change in ways productive, responsible, and valuable.

Our students must be skilled in *using* information and communication technology in their everyday lives. But as educators, we should focus not on merely imparting skills, but on creating opportunities for students to gain essential skills in the course of pursuing broader educational objectives.

## A University-wide, Across-the-Curriculum Approach

Examples of teaching and research projects that use information and communication technology in innovative ways can be found throughout the University. In addition, faculty in some departments, schools, and colleges study and teach about the cultural, economic, political, and social ramifications of the information revolution. But a lack of coordination, incentives, and sense of institutional purpose prevents many faculty from undertaking information technology-related projects and hampers the exchange of ideas among those who already are involved in projects.

A university-wide, across-the-curriculum approach is needed, providing faculty with the support they need and offering all students opportunities to use the state-of-the-art technology in education-enhancing ways while at the same time learning to think critically about the implications of the information revolution for the discipline they are studying as well as for the larger world. In our "ecology of experiments," we must continually share what we learn from these efforts across the curriculum, and build upon the best practices that emerge.

## New Learning Communities

The value of information — and knowledge — is being recognized as never before, and today's "knowledge economy" offers us new opportunities and challenges.

As a public institution dedicated to knowledge dissemination, the University of Michigan has a responsibility to reach out to communities of learners — including alumni and prospective students —

beyond its traditional, physical boundaries. As we venture into this new territory, we need to experiment with a variety of approaches — service, sponsored, and commercial — always mindful of our core values and mission.

We must consider as well our responsibility to communities on the other side of the digital divide, recognizing that e-outreach not only allows us to extend the university's assets to underserved communities, but also helps broaden the diversity of views within the university.

## Achieving the Vision

Our vision for the University of Michigan in the 21st Century is much more than a wiring diagram. However, none of our research, teaching, or outreach goals can be achieved without attention to infrastructure. In fact, increasing dependence on information technology already has strained our existing infrastructure to the point that we are no longer able to provide acceptable quality of service to the University community.

If we act quickly and boldly, we can make significant improvements within one year and regain national prominence in information technology infrastructure within three to five years. The physical infrastructure must be upgraded as soon as possible. We must rebuild our networks — in buildings, across campus, and to the outside world through upgraded Internet connectivity and Internet2 capability. Ultimately, we want to achieve a high level of end-to-end performance, such that faculty and students can move very large amounts of data rapidly from their desktops and labs to other points on or off campus, seamlessly, securely, and reliably.

Because many of today's high-end technologies will become tomorrow's basic infrastructure, we must continuously invest in pilot projects involving emerging technologies, such as wireless networking, so that we are in a position to more broadly implement those that prove successful and desirable.

We must also make a long-term commitment to recruiting and retaining sufficient numbers of highly skilled professional support staff and upgrading the information technology skills of all faculty, students, and staff.

Organizational and administrative changes are needed as well, with an appropriate balance between local provision of services and support and central guidance on standards and policies.

In short, if the University of Michigan is to become a living laboratory where faculty and students are engaged in a ground-breaking "ecology of experimentation," we must guarantee that no one is constrained by a lack of skills, technical support, computing power, network capacity, or connectivity, or by concerns about security. If all of that can be assured, we will be well equipped to swim into the next wave of the information revolution.

# Summary of Recommendations

Following is the complete list of detailed recommendations from the subcommission reports. Readers are directed to the Recommendations section of the main report for a contextual synopsis of the recommendations.

## *Infrastructure*

**A. Upgrading the Campus Physical Infrastructure**

1. Upgrade building wiring as needed to provide the capacity to support up to one (1) Gigabit per second (Gbit/s) connectivity to end-user locations, with minimum desktop performance of 100 Megabits per second (Mbit/s). This upgrade will take several years to complete, and should start soon and be sustained until completed.
2. Upgrade the campus backbone network to provide backbone bandwidth capacity to support ten (10) Gbit/s of aggregate service. This upgrade, including fiber optic cable, electronics, and necessary physical provisioning, should begin immediately.
3. Upgrade our external connectivity to provide sufficient levels of commodity and Internet2 connectivity in light of anticipated traffic growth stemming from increased demand and removal of artificial bottlenecks as the preceding upgrades are realized.
4. Coordinate efforts with the State of Michigan, telecommunications providers, peer universities, and the regional business community to locate a Network Access Point (NAP) in the southeast Michigan area, preferably in Ann Arbor.
5. Equip a much larger number of classrooms than at present with network access and a significant number of classrooms across the campus with multimedia access.
6. Maintain and enhance the important asset of the Media Union, which was created to facilitate advanced experimentation in the use of new media by students, staff, and faculty. It is vital that the technology in the Media Union be kept at the leading edge, and that the professional experts who can use, demonstrate, and teach the skills to apply that technology be retained.

**B. Experimental Deployment and Evaluation of Emerging Technologies**

1. *Pilot Wireless Infrastructure Initiative*: Start a focused Pilot Wireless Infrastructure Initiative to test the deployment of wireless networking on a large campus for planning and evaluation of a future pervasive campus installation.
2. *Advanced Technologies and Services for Emerging Applications*: Develop pilot projects and prototype demonstrations of services and technologies that support high performance research and instructional applications. This initiative is meant to exploit the full potential of emerging infrastructure and computing capabilities.
3. *Voice over IP Initiative*: Develop a plan to exploit the rapid convergence of voice and data networks into a "universal network," and to test the widespread deployment of Voice over IP technology to replace the University's legacy telephone system.

**C. Unbundling of Services and the Establishment of Pricing Guidelines**

1. The backbone network should be viewed as a strategic asset of the University. It should be provided to the campus as a commodity service with minimal bundling or tying with other services.
2. The idea of unbundled services should be a framework for pricing and cost allocation decisions. This approach should balance those services that are provided in a "common good" manner through central funding, and those specialized and/or advanced services that are cost-recovered via chargeback systems.
3. A "Campus IT Pricing and Services Commission" should be formed at a senior strategic level to advise the University executive officers on IT service and pricing recommendations.
4. A monitoring and measurement infrastructure should be deployed to aid in the collection and analysis of short-term and historical data for use in service measurement pricing and allocation decisions.

**D. Organizational Structure and Governance**

1. Executive and central IT leadership, with the cooperation of the campus IT organizations, must refocus to support the collaborative upgrade of the campus information infrastructure.
2. Central IT administration and the Provost's Office must begin to negotiate and initiate a concerted campus-wide building infrastructure upgrade plan with Deans and Directors.
3. IT Administration must streamline and optimize key committees such as the Strategic Directions Group (SDG) and the IT Federation. These groups should be coordinated with IT leadership to insure that their input and counsel are provided to the executive officers.
4. IT Administration must extend working corporate partnerships in IT for key areas of infrastructure development at all levels. Some areas for increased corporate partnership include the Pilot Wireless Infrastructure Initiative, campus-wide software licenses, campus-wide high performance end-to-end networking, and Voice over IP telephony.

**E. Creation of a Campus-wide Security and Information Assurance Function**

1. Ensure the security and privacy of valuable digital records and assets across campus through rigorous and continuous assessment of policies and practices on an ongoing basis.
2. Ensure implementation of baseline security in the University-wide IT infrastructure and services shared by both academic and administrative environments.
3. Establish mechanisms to ensure that "preventative IT security measures are available" to the entire campus.
4. Establish a "Crisis Response Team" representing campus IT service providers to coordinate a University-wide response to potential technology-based attacks or mishaps.

**F. The Recruitment, Training, and Retaining of IT Professional Staff**

1. The University must develop innovative compensation packages to reward excellence and to maintain a degree of parity with industry in recruiting and retaining professional IT staff.
2. The University should create internship and training programs, partnership programs, and transition programs to move recent graduates and support staff into IT professional roles.

## *What We Teach and How We Teach*

### Faculty and Graduate Students: Creating a new institutional environment for learning about the information revolution

**A. Physical and Human Infrastructure**

1. The University should make it a priority to equip a much larger number of classrooms than at present with network access and a significant number of classrooms across the campus with multimedia access.

2. The University should invest significant incremental resources to ensure that technical help is available to maintain equipment in working order and that instructional help is available to work in a "side-by-side" model for faculty and graduate students seeking to use information technology in teaching.

3. All support staff should be competent with information technology in their areas of responsibility. New hires should be required to have this competency; staff in place should be required to upgrade their skills to competency. The University should provide the training programs that will enable this.

**B. Dissemination and Coordination**

4. The University should create structures in which faculty, along with student and staff collaborators, work together and share their discoveries and expertise about information technology and teaching.

**C. Support Structures**

5. The University should establish processes by which faculty apply for release time specifically in order to establish or improve the instructional technology component of a new or existing course or to participate in the curricular development of new minors or concentrations on some aspect of the information revolution.

6. Departmental, college, and school executive committees should accept innovative and effective teaching, pedagogical research, and research with instructional technologies as a positive aspect of a tenure or promotion file.

7. Issues of intellectual property with regard to courses delivered by faculty and distributed by means of information technology should be clarified in ways that respect the interests of the faculty and the University.

8. The University should make target-of-opportunity funds available to hire faculty whose area of scholarship is in the information revolution, broadly conceived. These faculty should be cross-appointed to at least two disciplines or programs. These appointments should be distributed across the University.

**D. Graduate Students**

9. Graduate students should be given numerous and wide-ranging opportunities to work with faculty in developing uses of information technology in courses and in developing courses/curricula about the information revolution.

10. A number of centralized information technology facilities, available to graduate students and particular to their needs, should be established. These facilities should be devoted to areas of scholarly expertise that students from a variety of disciplines can draw on (e.g., the current GIS facility, computational modeling, large-scale database analysis, etc.).

## Undergraduate Students and Learning Outcomes: Creating a new institutional environment for learning about the information revolution

### A. Undergraduate Programs

11. Every undergraduate program should ensure that the significance of information technology and the information revolution is adequately and appropriately reflected in the program's curriculum.

12. Schools and colleges should be encouraged to adopt an "information revolution across the curriculum" approach to the teaching of the information revolution and information technology.

### B. Learning Outcomes

**Understanding the information revolution and evaluating its "information"**

13. Curricula at the University of Michigan should enable students a) to evaluate information and its reliability in a critical fashion; b) to incorporate information into a field of knowledge so that it serves a specific purpose or intellectual goal; c) to gain an understanding of the some of the cultural, economic, political, social and psychological implications of the information revolution and to grasp the legal and ethical issues it raises.

**Fluency and conceptual skills**

14. Schools and colleges should develop introductory information technology courses for credit that will realize the three learning outcomes outlined in recommendation 13. Sufficient sections should be made available to all students who wish to take them.

15. At the same time, the University should develop, perhaps through ITCS or CRLT, or through college and school learning centers, a series of non-credit workshops for students that address these learning outcomes. These workshops might also be made available to faculty, staff, and graduate students.

**Multimedia communication**

16. The University should develop an interdisciplinary concentration or major in multimedia studies. Possible participants in the concentration might come from, but need not be limited to, the School of Information, the School of Art and Design, the School of Music, the Department of Electrical Engineering and Computer Science, Department of Film and Video, Department of Communications, and Department of English.

17. The concentration or major should include a series of two or three well-publicized introductory or sophomore level courses open to large numbers of students not concentrating in multimedia studies.

**Collaboration using information technology**

18. All departments and programs should examine ways in which collaboration, including collaboration using information technology, can become both an activity and a learning outcome in their courses.

19. CRLT should mount workshops, in as discipline-specific a manner as possible, that demonstrate effective strategies for structuring and enabling student collaboration and that enable faculty and GSIs to understand and to teach undergraduates which collaborative tools are appropriate in different circumstances.

## Research

1. To advance research in the digital age, the University should aggressively invest and build leadership in a broad set of integrated technical and social initiatives to understand and use new information technology tools more profoundly in its mission of knowledge creation, dissemination, preservation, and application. The development and use of "knowledge networks" can serve as a guiding idea. The required strategy has three elements: increasing research *about* information technology and the information revolution, increasing research *using* information technology, and *exploiting the synergy* between these two modes:
   a) Research *about* fundamental information and communication technologies (ICT) and techniques:
      i) capturing, visualizing, mining, manipulating, and storing and retrieving data.
      ii) advanced computation and communication activities, such as computer modeling and simulation, high-performance computing, embedded and mobile systems, and distributed processing.
      iii) advanced security for data and communications.
   b) Research *about* crucial information and communication technology application areas, which builds on the fundamental areas listed above and takes the next step toward integrated knowledge networks. For example:
      i) collaboration technology.
      ii) digital libraries.
      iii) human/computer interaction.
   c) Research *using* information and communication technology in particular disciplinary or interdisciplinary domains, such as the arts, humanities, life sciences, physical sciences, and social sciences.

2. The University should develop integrated, cross-cutting initiatives towards the development of knowledge networks:
   a) Ubiquitous data-rich portals, interactive websites, and data delivery systems.
   b) New models for extramural collaboration.
   c) Initiatives to increase interdisciplinary activity.

3. Information and communication technology research should be fostered by improved infrastructure, development of specialized resources, and enhancing support, including:
   a) Development of a distributed but coordinated infrastructure to support information and communications technology for research.
   b) Improving and extending the basic physical ICT infrastructure as well as specialized, high-end technology application services to support research computing.
   c) Improving access to technical support and expertise by offering a basic level of support campus-wide, by establishing a single point of contact for those seeking information and communication technology resources.
   d) Improve training and credentialing of ICT professionals and students through creation of an ICT Training Institute.

4. Central ICT leadership at the University must:
   a) Lead and nurture an effective, interoperative ICT environment.
   b) Lead in coordinating innovation and marshalling resources to support it.
5. The University and the schools and colleges must recognize and reward faculty contributions toward the development of leading-edge information technology and communication applications and tools.

## E-Outreach

1. The University must engage in the knowledge economy with collective vision and foresight.
2. In this vision, the role of the central administration as coordinator, facilitator, leverager, and occasional initiator of e-outreach must be clearly established.
3. The University should pursue multiple modes of outreach — e.g., commercial, sponsored, and service — determining which modes will best advance the mission and express the values of the University in a given situation.
4. The central administration and the schools and colleges must establish incentives and support for those individuals and units who want to participate in this new economy.
5. The University must develop, coordinate, and maintain high-end production capabilities and a robust structure of "distribution channels," building upon the substantial assets it already holds.
6. The central administration must quickly resolve key policy issues that bear upon digital production and dissemination of information and knowledge:
   *a)* intellectual property policies (ownership).
   *b)* conflict of interest/commitment policies.
   *c)* advertising/endorsement policies.
   *d)* use of the University name/marks.
   *e)* terms of agreement and legal resources (e.g., releases) and awareness of the legal restrictions that apply to digital material and broadcasts.
   *f)* policies and models for external partnerships and agreements.
7. The central administration and the schools and colleges must develop effective mechanisms for vetting all outreach initiatives in terms of finances, legal constraints, academic mission, contribution to on-campus educational and research capabilities, and impact on other units and on the University as a whole.
8. The University should reexamine its relationship to critical learning communities.
9. The University should collectively engage in an aggressive program of experimentation in the area of location-independent instruction or distance learning, and should develop mechanisms for institution-wide sharing of experiences gained from ongoing experiments and mechanisms.
10. The University should take advantage of the collaboration support potential of the new technology to reach out to previously underserved communities, both to extend the University's benefits and to increase the valuable diversity of views within the university itself.

11. The University should accelerate its development of information technology for the conduct of routine business transactions, for providing information to the public, and for extending the social networks of its faculty, staff, students, and alumni.

# The Information Revolution: Why We Must Act

In 1645, Robert Boyle lobbied for the creation of The Royal Society of London by arguing that true scholarship takes place in an "invisible college" of distributed participants. Today his insight seems an extraordinary prophecy. New technologies for information processing and communications have brought an information revolution that has changed the world. The University must change as well if we are to remain at the forefront of instruction, research, and service. While the University of Michigan has a long and distinguished record of innovation in the application of information technology, past glory will not meet present and future needs. Transformative events require transformative action. Such action must take place now.

Information is generated and reproduced so rapidly and inexpensively that it overwhelms traditional selection and sorting mechanisms. Most of this information, including that used by students and faculty, is produced and disseminated by people outside of the academy. Much of it is irrelevant to the pedagogical and research missions of the University. Very little of it is subject to protocols of evidence, authentication, and verification of the kind that have long characterized education and research in the University. And yet: its capacities, our access to it, the ways we use it, the ways we understand it, the kinds of analyses we bring to it, and the kinds of analyses it enables us to bring to bear on our disciplinary research and teaching are transforming the University, the workplaces our students will go to, and (directly or indirectly) the lives of all of us.

Information technology, in the form of the Internet, has also dramatically changed the ways that individuals communicate with one another. Individuals and groups can collaborate easily across great distance. Since universities are places where both knowledge and information are generated through research, and disseminated (communicated) through teaching, the information revolution alters, and is altered by, universities. Of central concern to the commission, therefore, is how we as an institution can best capitalize on the opportunities, and address the challenges, resulting from the information revolution.

Of special interest to the commission was how the information revolution changes what it means to be an educated person—to be able to "swim" with sureness and adaptability in one's society and one's physical world. To be educated is to know something of the history, the cultural productions (in music, art, literature, film, religion, etc.), and the legal, political, economic, and social systems of at least one's own society. It is to understand something of the interrelatedness of one's own and other social, political, and economic systems. It is to know something of the physical laws of the universe and of the history of science and medicine. It is to be able to use effectively the "everyday technologies" of our lives, to understand their implications for our society, and to be able to shape those implications through shaping the technologies and/or their use.

Information technologies are "everyday technologies." Virtually every household in North America has a television; most have VCRs. The household without chip technology embedded in a clock, a radio, a timer is hard to find. Over 50 percent of Americans now have access to the Internet and use it regularly; a much higher percentage of those with college degrees use the Internet regularly. Eighty-five percent of University of Michigan students come here owning a computer. Ninety-seven percent use e-mail regularly.

As a result of the rapid dissemination of new information and new knowledge, even experts must constantly study to remain current in their specialties. Improving health and longer life spans mean that people will remain active longer, and the need to keep learning will become ever more acute. The quaint phrase "lifelong learning" is rapidly describing a basic condition of life. The old distinction between those who teach and those who learn is giving way to a new world in which everyone is a teacher and a learner, albeit in different ways at different times. The university of the 21st century will be both a physical place and a geographically distributed space of ideas and interaction — a living laboratory that supports ongoing experimentation in learning.

The information revolution has also spawned entirely new fields of study (e.g., computer science), new interdisciplinary domains (e.g., complex systems), as well as dramatic advances within existing fields (e.g., computational linguistics). The University of Michigan must be at the forefront of these areas by undertaking research not only into using information technologies but also undertaking research about these technologies and their implications for our work lives; our cultural productions; and our legal, political, economic, and social policies and relations.

Thus, the challenge before the University of Michigan is to remake itself in ways that enable it to take full advantage of the opportunities of new information technologies to further its teaching, learning, and research. And, just as scholars have always sought to bring their knowledge to bear on an understanding of the world in which they live as well as on the past that has shaped that world, so, too, the challenge to the University is also to take as an object of study the world produced by the information revolution to understand its implications and to enable us to better shape its consequences. The changes that lie ahead are both dramatic and subtle. The University of 2045, four hundred years after Boyle's vision of the "invisible college," will still be a physical place with faculty and students and classrooms. But it will also be a distributed learning environment with a presence in all parts of the world, linking together hundreds of thousands of people in an ongoing web of learning. This new university must be created, but it will not be created according to any particular plan. Instead, it will emerge from a process of directed discovery through an ecology of experiments that yield new information and communications technologies as well as reveal new and better ways of creating and sustaining the educated person.

The President's Information Revolution Commission was established to recommend appropriate actions for the University to take in light of the information revolution. Some of the specific questions that the commission addressed included:

- How does the information revolution affect education and research in a large, public, research university?
- What should we be teaching with regard to this "revolution" (or perhaps more properly, "evolution")?
- How does the information revolution affect whom we should be teaching?
- How should we make use of the opportunities the information revolution has created in both our teaching and research?
- What new research about information technology and the information revolution should we pursue?
- How do we create a university environment in which students and faculty are comfortable with, and open to, uses of information technology?

Four subcommissions were formed to address the challenges before the University. One focused on what we teach and how we teach. Another tackled the challenges of research in the information age. The third addressed the implications of a university whose borders are rapidly being eroded through interaction with a globally distributed learning community. The fourth examined critical infrastructure needs that must be addressed to begin the ecology of experiments that lie ahead. Each subcommission report stands on its own and is included in its entirety. This summary report does not recapitulate those reports but rather uses them as a map from which to explore what we must do in response to the information revolution, how we might do it, and what we will gain by doing so.

# What We Must Do

The challenges ahead are at once concrete and elusive. The subcommissions' efforts revealed many infrastructure improvements that are needed simply to allow the University of Michigan to remain at the forefront of this emerging era. These improvements are not merely one-time upgrades in technology; they constitute a new way of thinking about the centrality of information infrastructure in the life of the University. At the same time, the subcommission members discovered changes in attitude and organization that will be required if the University is to become the living laboratory in which the needed experimentation can thrive. These changes are less obvious and simple to direct than are infrastructure improvements. They require a change in the University's concept of itself, with requisite mobilization, enablement, and empowerment. In this section we first discuss the immediate improvements in infrastructure required to put the University of Michigan on its new course. Then we follow with a strategy for creating the ecology of experiments necessary to create the new University.

## *Critical Infrastructure*

The University's physical infrastructure has long been recognized as essential to its success. Information technology infrastructure is now as essential as the traditional physical infrastructure. The commission members heard much about how the University of Michigan has fallen behind in the deployment of information technology infrastructure. Technical vision, leadership, capital, and the will to follow

through are required immediately in the following areas: (1) human capital; (2) policies and management of information infrastructure, with special emphasis on information security and intellectual property issues; and (3) the campus' technical infrastructure with an emphasis on higher service capability. It is the responsibility of the University's senior administration and deans to ensure that the required robust, distributed but coordinated information technology infrastructure is realized throughout the University.

Key to this outcome is an increase in human capital in information technology, i.e., the skill base of the University's faculty, staff, and students. Without requisite skills to use information technology, the University community will not exploit the opportunities it offers. Many in the University now make routine use of electronic mail and word processing. Most are moving into the use of presentation graphics. Some are now using low-end video, analytical packages, simulations, and distance-education applications. The pace of this learning and practice needs to be accelerated. The University must invest significant additional resources in "side-by-side" teaching and consulting assistance for faculty, graduate students, and staff who use information technology in teaching and research. Internships, training programs, partnership programs, and transition programs must be created to move support staff quickly into roles as professional facilitators. Consideration should be given to creating a training institute, perhaps in the Center for Research on Learning and Teaching (CRLT) or another organization, that would provide workshops in discipline-specific use of information technology. Students should be encouraged to gain skill with information technology before applying to the University, and should be provided with opportunities to take non-credit workshops to build such skills after arriving. Information technology facilities should be available to graduate students in areas of their scholarly expertise to enable them to work with faculty in applying information technology in instruction and research. Special consideration should be given to new hires who show special competence in use of the technology. Innovative compensation packages should be used to reward excellence and to maintain parity with industry in recruiting and retaining skilled people.

An essential part of the University's human capital in the area of information infrastructure is its professional staff for the design, management, and support of information technology. Like many other institutions, the University has had difficulty adapting to both rapid growth and change in the composition of demand for personnel in this area. We strongly recommend a multifaceted approach to assuring the University's ability to recruit, train, develop, and promote IT professionals. One area that needs immediate attention is the articulation of the University's personnel policies with the IT labor market. We suggest that the Associate Vice President for Human Resources and Affirmative Action be charged with working with a small group of IT managers and professionals to revise and streamline policies and practices so that the University can provide competitive compensation packages in this rapidly changing area.

The University must strengthen its capability in policies and management of information infrastructure, from the highest level of executive leadership to the schools and departments. The governance structure for managing information infrastructure should be revised. Central guidance should be provided in the areas of financial control, legal issues such as intellectual property, security and risk management, adherence to the academic missions of the University, and coordination of overall

services in efficient and effective ways for the collective good. At the same time, local services should be provided whenever possible through stronger capability and leadership within schools. Mechanisms should be created to provide guidance at all levels of leadership in service provision and pricing, assisted by monitoring and measurement capabilities that provide data to inform that leadership.

As the University's dependence on information technology has increased, demand has grown beyond the capabilities of the current physical infrastructure. We find ourselves unable to provide acceptable quality of service to the University community. Our University must successfully deploy a high-function, heterogeneous information technology infrastructure that will support a high level of "end-to-end" performance — e.g., that will permit faculty to move data, very rapidly and in very large amounts if need be, from their desktops and labs to other points on campus or off campus, seamlessly and reliably. To meet this goal, we must do three things at once: (1) upgrade in-building network infrastructure; (2) upgrade campus backbone infrastructure; and (3) upgrade external Internet connectivity, including provision of Internet2 capability on all parts of campus. Immediate and continuing attention is needed to address these upgrades, which demand a high degree of coordinated and sustained effort. In addition, the University's television and radio infrastructure must be improved to keep abreast of practice in the realm of digital broadcasting. Another important need is to strengthen the laboratory for advanced media experimentation found in the Media Union, and to extend that laboratory throughout the University. Additional technical details and minimal acceptable future targets are provided in the Infrastructure Subcommission report.

## *The University as an Ecology of Experiments*

To be "educated" today is to be able to swim easily in the world of the information revolution. It is to know something about the "information evolution" of the last fifty years and of its social, cultural, economic, political, legal, and psychological implications. It is to be able to use information technology wisely, strategically, ethically, and effectively. It is to be able to "read" contemporary information produced or presented by means of this technology. It is to be able to deal with data sets using this technology. In a world of multimedia, it is to be visually and aurally literate. It is to be able to "manage" the vast amounts of information now available, to be able to think about "information systems," and to be able to make accurate judgments about the accuracy and value of any particular "information."

To be an educator in a world in which the technologies and effects of the information revolution are ubiquitous is to go well beyond the information technology "skills" training that characterizes much of the public call to higher education around questions of information technology. It is to reach for learning outcomes that are an integral part of our disciplines and our curricula. It is also to reach for learning outcomes that address the subject of the information revolution in its own right, approaching it with the same rigor — the same attention to historical evidence, empirical data, and discourse analysis — that we demand of the rest of our research and teaching. It is to create a campus environment open to, comfortable with, and intellectually excited by innovative uses of information technology and their ensuing consequences, intended and unintended. It is to create an environment in which pedagogical and research experiments relating to the information revolution thrive.

Technology can facilitate effective learning: it can improve details of course management, methods of course presentation and delivery, and the processes of discovery and practice in the laboratory and the classroom. Hence, we must experiment with the technologies that underlie the information revolution within the context of learning. However, we must remember that these technologies can "lock in" poor pedagogical practices, block student-faculty interaction, and encourage research and scholarship that is too narrowly focused. It is imperative, therefore, that we evaluate the use of information technology with the same qualitative and quantitative rigor that we use to evaluate other innovations in teaching and research. To justify adoption, a technological innovation should either make learning more efficient, for example by freeing up time for critical tasks and requiring less emphasis on "routine" business, or more effective, for example by increasing the depth or breadth of investigation and incorporating more people in the learning process. Technological innovations that improve learning merit wide adoption; those that inhibit learning should be abandoned.

We need not only to teach about the information revolution but also to advance research into information technology itself, in areas such as high-performance computing, embedded and mobile computing, and security. When research discoveries in these areas lead to new capabilities, the focus shifts from fundamental research to ongoing refinement and extension of the advances into new applications. This kind of research is as important as fundamental research, because it helps to build the capacity for research in the broad sense. It is important that the University pursue research into the application of information technology to acquisition, storage, manipulation, and visualization of information, as well as to communications of data and ideas. New capabilities in areas such as collaboration technology, digital libraries, and improved human-computer interaction offer special promise of breakthroughs. The successful application of information technology has strengthened and will continue to strengthen scholarship and creative activity in the arts, business, engineering, humanities, life and health sciences, physical sciences, and social sciences. Beyond this, we need to scrutinize, with all the rigor a research university can bring to bear, the political, legal, economic, social, psychological, and cultural implications of the information revolution.

As a consequence of the information revolution, the physical, economic, and intellectual boundaries of the University are being extended to new venues, new audiences, new collaborations, and new modes of action. The ability to function well in this new University will be developed through learning by doing. Thus, we must engage in an aggressive program of experimentation in the area of location-independent instruction or distance learning. This experimentation should take advantage of the potential of the new technology to support us as we reach out to previously underserved communities, both to extend the University's benefits and to increase the valuable diversity of views within the University itself. The emergence of Internet-based ventures for disseminating knowledge products, such as Fathom.com and UNext.com, might provide important new mechanisms for people to engage in an ongoing learning process in a rapidly changing world. When appropriate, the University should partner with such ventures, or undertake them on its own. Important experiments in these areas are already underway at the Flint and Dearborn campuses, and should be expanded. New technology can be applied to all aspects of the University's business, including routine business transactions, information services for the public, and expansion of social networks among faculty, staff, students, alumni,

and the people of Michigan. Special attention should be given to more effective use of the University of Michigan's communications assets in radio and television, which have not been fully exploited.

# Recommendations

As mentioned above, the four subcommission reports provide detailed recommendations as to what should be done. This section highlights key aspects of those recommendations.

## *Critical Infrastructure*

The University of Michigan has fallen behind in the deployment of information technology infrastructure. Technical vision, leadership, capital, and the will to follow through must provide the next generation of information technology infrastructure at the University. The central administration and deans must lead and nurture the creation of an effective information technology infrastructure for the University's research and instructional missions. The ideal is to create a distributed but coordinated information technology infrastructure support program throughout the University.

This infrastructure includes the following:

1) Human capital
2) Policies and management for information technology
3) University-wide security and quality assurance
4) Physical infrastructure, including buildings, network backbone, and Internet connectivity
5) Advanced technologies and services for emerging technologies

Human capital is required for successful use of information technology in instruction, research, and administration. Faculty, staff, and students must have their skills upgraded and maintained at a high level of competence. This should be accomplished through recruitment and through in-house training. It is especially important that the University meet the challenges of recruiting, developing, and retaining qualified IT staff in the current, highly competitive market. A long-term commitment must begin immediately to hire needed professional staff and to maintain professional skill sets through ongoing training and retraining. This will require innovative compensation packages to reward excellence and to maintain parity with industry in recruiting and retaining professional staff. Internship and training programs, partnership programs, and transition programs can help to move support staff into professional IT roles.

Policy and management for information technology must be strengthened across a variety of fronts. Leadership must be provided from the highest executive levels of the University, extending down to the schools and departments. Central guidance should be provided in the areas of financial control, legal issues such as intellectual property and risk management, adherence to the academic missions of the University, and coordination of overall services in efficient and effective ways for the collective good. A

governance structure for managing information infrastructure should be devised that presumes local services will be provided as often as possible by local service units.

The University increasingly faces the dual challenge of protecting systems and services from outside attacks while protecting the external Internet from attacks originating within the University. A campus-wide security and information assurance office should be created with appropriate representation from various IT administrative units. This office should assess and review campus-wide security policies and practices on an ongoing basis in order to ensure security and privacy of valuable digital records and assets across campus through rigorous and continuous assessment of policies and practices on an ongoing basis. This would ensure implementation of baseline security in the University-wide infrastructure. A crisis response team representing service providers on campus should be established to coordinate a University-wide response to potential technology-based attacks or mishaps.

The University's dependence on information technology has grown beyond the capabilities of the current infrastructure. We must deploy a highly functional, heterogeneous physical infrastructure to support necessary "end-to-end" performance. We must be able to move data very rapidly in large quantity, seamlessly and reliably, from desktops and labs to points on campus and off campus. Five classes of upgrades are immediately required:

1) Upgrade in-building network infrastructure to provide the capacity to support up to 1Gbit/s connectivity to end-user locations, with minimum desktop performance of 100 Mbit/s. This midterm upgrade will take many years and should start soon and be sustained until completed.
2) Upgrade campus backbone infrastructure to provide backbone bandwidth capacity to support target 10 Gbit/s aggregate service. The upgrade, including fiber, electronics, and necessary physical provisioning, should begin immediately.
3) Upgrade external Internet connectivity to provide sufficient level of commodity and Internet2 connectivity in light of anticipated traffic growth stemming from increased demand and removal of artificial bottlenecks as the preceding upgrades are realized.
4) Equip a much larger number of classrooms than at present with network access and a significant number of classrooms across the campus with multimedia access.
5) Maintain and enhance the important asset of the Media Union, which was created to facilitate advanced experimentation in the use of new media by students, staff, and faculty. It is vital that the technology in the Media Union be kept at the leading edge, and that the professional experts who can use, demonstrate, and teach the skills to apply that technology be retained.

Once specialized services have become widespread and basic, gaining experience with new technologies early in the cycle greatly facilitates their widespread deployment later in the cycle. The University's administration should invest in pilot projects and experimental evaluations to integrate new core and specialized services that support teaching and research needs. Focused investments should be made in the following right away, with other new initiatives to follow:

1) A pilot wireless infrastructure initiative to test deployment on a large campus for the purpose of planning and evaluation of a future pervasive campus installation.
2) Several prototype demonstrations of advanced information technology services underlying research and instructional applications.
3) A pilot Voice over IP initiative to exploit the rapid convergence of voice and data networks into a "universal network."
4) A high-performance computing and networking initiative to take advantage of the full potential of emerging infrastructure and computing capabilities.

## *What We Should Teach*

The information revolution is changing what it means to be an educated person. The University of Michigan must assume leadership in learning and scholarship regarding the information revolution and the use of information technology in teaching and learning. As a first step, every undergraduate program should ensure that the curriculum adequately reflects the use of information technology in, and the implications of the information revolution for, work in the discipline. This "information revolution across the curriculum" approach to the teaching of the information revolution and information technology should go along with "hands on" experience of using real computerized data banks, doing computerized modeling, using computer software to do data analysis, etc., while at the same time learning something of the larger cultural and social issues and implications of the information revolution.

The University of Michigan should enable students to learn to (a) evaluate information and its reliability in a critical fashion; (b) incorporate information into a field of knowledge so that it serves a specific purpose or intellectual goal; and (c) become aware of some of the cultural, economic, and political implications of the information revolution and to grasp the legal and ethical issues it raises.

The discussion of what we should teach regarding the information revolution must begin with a basic question: what constitutes information? The following observations provide an initial guide:

- Information is not the same as knowledge. Students need to learn that knowledge involves the use of information, but that knowledge is both personal and communal and the learning process has personal and social dimensions that information gathering per se lacks.
- Existence of information does not guarantee communication. Students need to know that the existence of web-based communication, divorced from conventional cues between speakers, can lead to miscommunication.
- Information becomes meaningful only in a context. Students need to know that context matters and how to understand context.

- Information is not necessarily reliable, accurate, or valid. The need to evaluate information in a critical fashion becomes particularly urgent with web-based information given the web's leveling of sources and its lack of structure, convention, and protocols for authentication. Students need to learn how to evaluate web-based information.

The information revolution also calls into the foreground many legal and ethical issues that students must understand, including:

- Responsibility with respect to information production and dissemination. Students need to understand their responsibility for the reliability of information that they produce and disseminate (students-as-authors), in addition to their responsibility for assessing the validity and reliability of the information that they consume (students-as-readers).
- Responsible and irresponsible use of common information resources and the burdens on public goods created by certain kinds of private actions such as MP3 downloading and spamming. Students should habitually consider whether their private actions using IT are acceptable or whether, and under what conditions, they might be burdensome and negatively affect others.
- Principles governing privacy, security, and access to information. Students should be able to reason about when limits on access become censorship and who should have access to different classes of information.
- Issues regarding ownership of information, when information becomes intellectual property, and the philosophical and commercial implications of controversies such as open source vs. commercial software. Students need be aware of the bearing of such issues on their conduct in the digital world, and they should be able to engage in thoughtful discussion of the issues.

Finally, the information revolution brings new social, cultural, legal, economic, political, and psychological implications, such as:

- Cultural differences in the understanding of information content and in the use of information and information technologies. Students should be able to assess the impact of information and information technologies on particular organizations and groups within society, and the ways in which people can shape the impact of technology.
- Implications of the "digital divide," the influence of information literacy on one's place in society, and its role in building social capital.
- Effects on globalization and multinationalism. Students should be thoughtful about questions such as whether the information revolution promotes cultural hegemony or enables cultural diversity, or whether it should (or can) be managed to promote particular cultural and social goals.
- Responses of power structures in an "information economy." Students should understand implications for the workplace, education, and entertainment. They should understand how different people attribute value to information and what impact pricing decisions can have on access and use of information.

Most students enter the University of Michigan with some computing "skills," but those skills do not run very deep and often do not rest on a solid conceptual understanding of information technology. When students (or faculty) know only about computer "applications," they are not in a strong position to use information technology wisely. All students at the University of Michigan should be armed with the conceptual skills that will allow them to employ information technology wisely, both in their various academic disciplines and in their personal lives. Different academic disciplines use information technology in different ways, but certain key concepts and skills are universally helpful — at least in enabling people to comprehend and to adapt to ongoing, rapid technological change.

In addition to understanding the basics of computation and information technology, students should understand communications technology and media. Of particular importance is multimedia communication involving combinations of different media: video streaming, web pages, presentation graphics, photography, and other visual forms; audio (in all its forms); and tactile feedback (e.g., the new PC mouse that feeds back texture and touch, or fully immersive environments). Traditional, print-based education does not prepare us to use new multimedia capabilities effectively, critically, or with deep understanding. Appropriate learning outcomes regarding multimedia should address the reading, use, and production of multimedia content. They must also address the unique properties of each medium and of multimedia combinations, and the knowledge and skills relevant to those unique properties. In addition, students must learn how to engage with multimedia as a basic form of communication. They need to know how to utilize multimedia technology when they do research, gather data, organize information content, deliver content, and gather, assess, and respond to feedback.

## *How We Should Teach*

There are many teachers at the University of Michigan who use information technology in creative and highly effective ways. They have not simply updated traditional courses by using computer-generated slides or by relying on electronic rather than paper documents. Rather, they have taken to heart the ideas of truly effective education: their students are engaged, "active" learners; they demand that students think critically and then argue for and defend their ideas; their students learn by teaching; they present challenging problems that relate theory to the real world. And then they use technology to provide greater engagement, deeper involvement, more complex or challenging problems, or fuller exchange of ideas. Unfortunately, these individuals are not in the majority, and there is little cross-fertilization between units. Many faculty could be inspired and enabled to adopt new approaches and methods in their teaching if provided with access to relevant and stimulating examples, plus specific advice and encouragement. There must be added emphasis on adapting or transferring successful applications across disciplines, with concomitant attention to providing adequate support structures such as side-by-side consulting expertise.

Good teaching is a high priority at the University of Michigan; however, faculty recognize that promotion and tenure committees place a high premium on strong research, often evaluated by long-entrenched metrics. Heavy personal investment in instructional technology has little or no automatic payoff in academic performance review. The time required to experiment with new technologies in

teaching is time taken from activities that seem more likely to lead to tenure, promotion, and merit increases. Moreover, lack of clarity about issues of intellectual property is another likely inhibitor of some faculty efforts in these directions. College and school executive committees should accept innovative and effective teaching, pedagogical research, and research with instructional technologies as a positive aspect of tenure or promotion files. Policies for intellectual property in courses developed by faculty and delivered by means of information technology should be clarified in ways that respect the interests of the faculty and the University.

Graduate students are especially well positioned to connect potential applications of information technology to emerging developments in their fields. As the next generation of teachers, researchers, and skilled practitioners, they are expected not only to master the basic contours of their discipline, but to contribute to its latest advances. The prominence of new technologies in helping to reshape many of these disciplines requires graduate students to be trailblazers in realizing unsuspected possibilities for information technology in their field. Cases of reverse mentoring, where graduate research assistants guide and instruct faculty in this area, are familiar in the sciences and humanities. Graduate students should therefore be given numerous and wide-ranging opportunities, including in their roles as GSIs, to work with faculty in developing uses of information technology in courses and in developing courses/curricula about the information revolution.

## *Our Research Agenda*

The information revolution, spurred by research, is also transforming the pursuit of knowledge and understanding in virtually all fields of research, and is fostering exciting new interdisciplinary collaborations. Ubiquitous, high-performance computing and communication are connected by distributed operating systems, linking people with vast collections of multimedia information, tools for analysis and synthesis, and collections of facilities and instruments on a global scale. Supercomputers and immersive visualization facilities augment both individual and team-based creativity and discovery. These linkages are relaxing the barriers of time and distance in support of broader participation in research and inquiry-based learning. They are putting powerful new tools — new lenses, in a manner of speaking — in the hands of communities of scholars, changing their research landscape from one of relatively isolated, self-contained experiments, texts, and analyses to a vast potential network of data and interpretations. This network of information and knowledge, continually evolving, represents a dynamic field for exploration. In this environment, the very nature of research is changing: where there was once analysis, there is now also integration and synthesis; where there was once observation, there is now also modeling and structured querying of vast amounts of information; where there was once the static record of phenomena, there is now also the real-time accumulation and compilation of data. To advance research in this environment, the University should aggressively invest and build leadership in a broad set of integrated technical and social initiatives to understand and use these new tools more profoundly in its mission of knowledge creation, dissemination, preservation, and application.

The required strategy has three elements: 1) increasing research about information technology and the information revolution, 2) increasing research using information technology, and 3) exploiting the synergy between these two modes. In the last forty years, the explosive growth of knowledge in infor-

mation technology has led to new fields (e.g., computer science), new interdisciplinary domains (e.g., complex systems), and advances of all sorts within existing fields (e.g., computational linguistics). Such knowledge continues to grow at a staggering rate. The University of Michigan can and must play a key role in expanding and utilizing this knowledge, or it consigns itself to a secondary position in American education. A coordinated approach to theory and practice of information technology across research areas is required for the University to be a laboratory for the ecology of experiments that will define the research university of the future.

A key area of need is an improved means to deal with the explosion of data in many research areas. Gigabyte databases are increasingly common in the humanities, as well as the social, life, and medical sciences. Terabyte and even petabyte databases are becoming common in some areas of physical science. The research infrastructure of the University must be ready to handle this expansion and to help support the capture, analysis, delivery, and access of data-rich research. Data visualization, data mining, and data storage and retrieval are key areas of potential improvement. Improved data visualization is needed to present and manipulate large quantities of data to take advantage of the inherent ability of researchers to process visual data and detect patterns through inspection. Automated techniques are required to "mine" the data, looking for hidden quantitative and qualitative regularities and patterns. Advances in data mining and data manipulation promote discovery of unexpected regularities and thereby the development of new theories in many fields, including the physical sciences, the life sciences, the social sciences, and the humanities.

Massive databases must be stored, maintained, and accessed. Fundamental research issues in storage, access, reliability, and security must be addressed before networks of knowledge can be built at global scale; and emerging modes of information technology — such as embedded and highly mobile computing — must be developed and better understood. Some of these issues, such as security and reliability, are inherent to data, computation, and communication. Security is an especially important area in which the University of Michigan has the potential to become a national leader.

At the same time that we engage in research that enables us to maintain leadership in the information technology area, the University must also take leadership in research that analyzes the effects of the information revolution. Such research should advance our understanding of the many social and psychological consequences of the information revolution; it should enable us to understand how the information revolution affects economic and political and labor relations; it should address the many legal and intellectual property issues around information technology; and it should further our understanding of the capacities of this technology in cultural production and our ability to "read" the theatre, music, dance, visual, and performance art produced using this technology. Effective research about these large implications of the information revolution would make the University of Michigan a national and international leader in scholarship and policy setting with reference to the information revolution. To do this we will have to embark on a program that hires new faculty and trains new graduate students.

## Outreach and the New Learning Community

The University must use collective vision and foresight to fulfill its institutional mission in the age of the information revolution and in the dynamic and still unstable information- and knowledge-based economy that is emerging. This requires reexamination of relationships with critical learning communities. As people become "lifelong learners," the University's challenge will be to maintain a lifelong relationship with an extended community consisting of prospective students, current students, and alumni. In addition, the University's community is increasingly global. The University must assert its core missions in the light of dramatically new modes for the generation, preservation, and dissemination of knowledge. As a public institution operating in the new knowledge economy, the University of Michigan has special responsibilities to the concept of community. It must help shape the new economy by wise preservation and dissemination of its knowledge assets, striking a balance between commercialization opportunities and the needs and values of service and scholarship. It must reach out to those on the other side of the digital divide, in an effort to lessen that divide. The University should take advantage of the collaboration support potential of the new technology to reach out to previously underserved communities, both to extend the University's benefits and to increase the valuable diversity of views within the University itself. It must work to understand globalization, and to ensure that globalization is not tantamount to cultural imperialism, inside academe or out. The opportunities that the University seizes in this environment should fit with the mission of the University and be in keeping with the free interchange of ideas and the University's tradition of commitment to diversity and access.

The University's central administration has special obligations with respect to these challenges. It must facilitate, leverage, and occasionally initiate outreach activity. It must coordinate activities among the various units, facilitating their electronic outreach activities with appropriate infrastructure, incentives, and policy clarification. It must leverage opportunities where individual units lack sufficient leverage and promote University-wide partnerships in an environment of experimentation and innovation for electronic outreach. It must provide an enlightened institutional environment that deals effectively with intellectual property, conflict of interest and commitment, advertising and endorsement opportunities such as the use of University name/marks, terms of agreement and legal resources, and restrictions related to digital material and broadcasts and external partnerships and agreements. It must accelerate its development of information technology for the conduct of routine business transactions, for providing information to the public, and for extending the social networks of its faculty, staff, students, and alumni. Finally, the central administration must develop effective mechanisms for evaluating all outreach initiatives in terms of finances, legal constraints, academic mission, contributions to educational and research capabilities on campus, and impact on other units and on the University as a whole.

The University should engage in an aggressive program of experimentation in the area of location-independent instruction or distance learning and should develop mechanisms for institution-wide sharing of experiences gained from ongoing experiments. The University will only learn how to carry out effective distance education by doing distance education; it must be prepared to make mistakes and to share its experiences across the institution. The University as a whole, both centrally and within the

schools and colleges, must develop, coordinate, and maintain high-end production capabilities and a robust structure of "distribution channels." This means building upon the substantial assets it already holds, as well as creating new capabilities. The skills and infrastructure must be in place to exploit presentation graphics, video, simulations, full-blown distance-education courses, and digital dissemination that can compete for the attention of the public-high-end production. The University also must improve its capabilities for distribution of media to compete effectively with other service providers and deliver quality content. It is particularly important that the University assess and enhance its distributed broadcast capabilities — its television, radio, and Internet broadcast capabilities — in light of impending digitization, and develop means for more effective and coordinated use of those broadcast capabilities as a major and irreplaceable e-outreach asset.

## What We Stand To Gain

The university is one of civilization's most enlightened creations. It simultaneously preserves knowledge and creates new knowledge that often upsets the old. A great university must be forever off-balance, caught between the past and the future. The information revolution provides a particularly disequilibrating time for the University. The magnitude of change it brings has been likened to the discovery of fire, of writing, and of printing. Information is at the heart of learning and of knowledge. If we are in an information revolution, we are in a university revolution as well.

At best, we point in a direction that must be traveled to be discovered. Nevertheless, the challenge before us is so pressing and the stakes so high that we dare not hold back. It is the duty of a great university to reach beyond what is known, even when that means going beyond our own well-known ways of doing business. While the recommendations of this report start us on the journey, the journey itself will require constant reassessment and correction.