The Impact of Information Technology on the Future of the Research University

An Update on a National Academies Study

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Introduction

A decade ago, many people had yet to accept that the inexorable progress of information technology (IT) would result in fundamental change in universities. Experience is shrinking that group. The basic premises that underlie the need for change are the same today as they were then, but now they are even more compelling:

- The modern research university provides a range of functions that are incredibly important to our society, all of which are highly information intensive.
- IT will continue to become faster and cheaper at an exponential pace for the foreseeable future, enabling alternatives to the ways that universities have traditionally fulfilled their various functions—and possibly even to the university as provider of those functions.
- It would be naïve to assume that, unlike other businesses, the availability of these alternatives will not transform both the roles and character of the university.
- Precisely because of the importance of the functions provided by the research university, it behooves us to explore deeply and critically what sorts of changes might occur so that, if they do occur, we are better prepared for them.

It's hard for those of us who have spent much of our lives as academics to look inward at the university, with its tradition and obvious social value, and accept the possibility that it might change in dramatic ways. But although its roots are millennia old, the university has changed before.

- In the 17th and 18th centuries, scholasticism slowly gave way to the scientific method as the way of knowing truth.

- In the early 19th century, universities embraced the notion of secular, liberal education and began to include scholarship and advanced degrees as integral parts of their mission.
- After World War II, they accepted an implied responsibility for national security, economic prosperity, and public health in return for federally funded research.

Although the effect of these changes have been assimilated and now seem natural, at the time they involved profound reassessment of the mission and structure of the university as an institution.

The National Academies Project

To better understand the implications for the research university, in February 2000 the National Academies convened a steering committee that, through a series of meetings and a workshop, produced the report *Preparing for the Revolution* (National Academies Press, 2002). Subsequently, the Academies have created a roundtable process to encourage a dialog among university leaders and other stakeholders, and in April 2003 held the first such dialog with university presidents and chancellors.

The premise of the National Academies studies was a simple one:

The rapid evolution of digital technology will present many challenges and opportunities to higher education in general and the research university in particular. Yet there is a sense that many of the most significant issues are neither well recognized nor understood either by leaders of our universities or those who support and depend upon their activities.

The first phase of the project was aimed at addressing three sets of issues:

1. To identify those technologies likely to evolve in the near term (a decade or less) which might have major impact on the research university.

2. To examine the possible implications of these technology scenarios for the research university: its activities (teaching, research, service, outreach); its organization, structure, management, and financing; and the impact on the broader higher education enterprise and the environment in which it functions.

3. To determine what role, if any, there was for our federal government and other stakeholders in the development of policies, programs, and investments to protect the valuable role and contributions of the research university during this period of change.

The steering group for the effort was comprised of leaders from higher educatin (e.g., Frank Rhodes, Joe Wyatt), the chief technology officers of major IT companies (IBM, Bell Labs, Xerox), and several leaders in science policy (Bill Wulf,)

Over two years the steering group met on numerous occasions to consider these issues, including site visits to major technology laboratories such as Bell Labs and IBM Research Labs and drawing upon the expertise of the National Academy complex.

Two years ago we assembled over 100 leaders from higher education, the IT industry, and the federal government, and several private foundations for a two-day workshop at the National Academy of Sciences to focus our discussion.

Beyond the insight brought by these participants, perhaps even more striking was their agreement on a number of key issues that frame the content of my remarks this morning.

The first finding of the Academies' steering committee was that the extraordinary pace of the IT evolution is likely not only to continue but could well accelerate.

One of the hardest things for most people to understand is the compound effect of this exponential rate of improvement. For the past four decades, the speed and storage capacity of computers have doubled every 18 to 24 months; the cost, size, and power consumption have become smaller at about the same rate.

As a result, today's typical desktop computer has more computing power and storage than all the computers in the world combined in 1970.

In thinking about changes to the university, one must think about the technology that will be available in 10 or 20 years, technology that will be thousands of times more powerful as well as thousands of times cheaper.

Put another way, over the next decade, we will evolve from "giga" technology (in terms of computer operations per second, storage, or data transmission rates) to "tera" and then to "peta" technology (one million-billion or 10^{15}).

For planning purposes, we can assume that within the decade we will have infinite bandwidth and infinite processing power (at least compared to current capabilities).

We will denominate the number of computer servers in the billions, digital sensors in the tens of billions, and software agents in the trillions. The number of people linked together by digital technology will grow from millions to billions.

We will evolve from "e-commerce" and "e-government" and "e-learning" to "e-everything", since digital devices will increasingly become our primary interfaces not only with our environment but with other people, groups, and social institutions.

The second finding of the committee, in the words of North Carolina State University chancellor Mary Anne Fox, was that the impact of IT on the university is likely to be "profound, rapid, and discontinuous," affecting all of its activities (teaching, research, service), its organization (academic structure, faculty culture, financing, and management), and the broader higher education enterprise as it evolves toward a global knowledge and learning industry.

If change is gradual, there will be time to adapt gracefully, but that is not the history of disruptive technologies. As Clayton Christensen explains in *The Innovators Dilemma*, new technologies are at first inadequate to displace existing technology in existing applications, but they later explosively displace the application as they enable a new way of satisfying the underlying need.

Although it may be difficult to imagine today's digital technology replacing human teachers, as the power of this technology continues to evolve 100- to 1000-fold each decade, the capacity to reproduce with high fidelity all aspects of human interactions at a distance could well eliminate the classroom and perhaps even the campus as the location of learning. Access to the accumulated knowledge of our civilization through digital libraries and networks, not to mention massive repositories of scientific data from remote instruments such as astronomical observatories or high-energy physics accelerators, is changing the nature of scholarship and collaboration in very fundamental ways. Each new generation of supercomputers extends our capacity to simulate physical reality to a higher level of accuracy, from global climate change to the biological function at the molecular level.

The third finding of the committee suggests that although information technology will present many complex challenges and opportunities to universities, procrastination and inaction are the most dangerous courses to follow during a time of rapid technological change.

After all, attempting to cling to the status quo is a decision in itself, perhaps of momentous consequence. To be sure, there are certain ancient values and traditions of the university, such as academic freedom, a rational spirit of inquiry, and liberal learning that should be maintained and protected. But just as it has in earlier times, the university will have to transform itself once again to serve a radically changing world if it is to sustain these important values and roles.

Following the publication of *Preparing for the Revolution*, the Academies formed a standing roundtable to facilitate discussion among stakeholders.

We have now moved into the second phase of our studies, with a number of activities this year:

THE AAU PRESIDENTS WORKSHOP – April 15, 2003

We managed to persuade the AAU presidents to stay on for an additional day after their spring meeting to participate in a summit meeting concerning "The Transformation of Research Universities through Information Technology".

We began the meeting by asking Lou Gerstner, former CEO of IBM, to kick off the meeting the evening before with a dinner address, describing how he had transformed IBM. Gerstner hit them over the head with a 2x4 by noting that when he took over the leadership of IBM, the company's stock had collapsed to only 20% of its high value, and they were about ready to break up the company. He conveyed two lessons learned:

1. Despite the fact that IBM was developing much of this technology, they really didn't understand its disruptive character for their own corporation;

2. Second, that technology strategies today require the attention of the very highest level of an organization's leadership to simply delegate this assignments to others such as CIOs or CFOs puts the organization at great risk.

With full awareness that university presidents listen most carefully to their own voices, we structured workshop the next day into three panels of presidents:

First, we asked several presidents (including Chuck Vest, Nancy Cantor, James Moeser, and Bob Berdahl) to discuss what was currently in their in-out box, the here-and-now issues. As you can imagine, these included concerns such as how they could meet the seemingly insatiable demand for computing resources (particularly bandwidth); how they could pay for this technology; and how they could handle privacy and security issues. You will also probably not be surprised that most of the presidents boasted that they had these issues well in hand (a perception quite different than we were to find with their provosts several months later).

We then tried to move the presidents group somewhat farther into the future, by asking them to speculate about technology challenges for the decade ahead. Here, we stimulated the discussion by having members of the IT Forum toss occasional hand grenades into the conversation.

- For example, Stu Feldman of IBM asked how the presidents would respond to the strong possibility that he would be able to hand them a device the size of a football (choosing an object particularly familiar to university presidents) that would contain the entire Library of Congress.

- Dan Atkins, coming off his recent experience as chair of the NSF Blue Ribbon Panel on Cyberinfrastructure, asked how the presidents believe faculty loyalty and mobility would be affected by the rapid emergence of knowledge nets, cyberspace-based environments for scientific collaboration clearly independent of space and time.

Finally we turned to an operational discussion of how the National Academies, federal agencies such as NSF, and our IT Forum could help the presidents in providing leadership during this period of transformation.

Some comments of particular note:

1. Bob Dynes (UC San Diego) observed that technology is moving so fast that there are vast differences between the seniors and the freshmen at his institution. The freshmen are completely wireless, and communicating in very unexpected ways. If we enable students, they will drive us. He also noted that campus boundaries are less and less meaningful, which poses additional challenges.

2. Louis Gerstner raised two in his keynote talk: (1) Is it possible to manage universities as unified enterprises, or will they always function as decentralized entities? and (2) Will the university build its value proposition around the student (e.g. the University of Phoenix) or the professor?

3. Stuart Feldman (IBM) conjectured that the breakdown of campus borders highlights the need to think strategically about IT and its influence on the institution. E-infrastructure can disintegrate, disaggregate, reintegrate and reaggregate functions and roles of a university. He questioned whether the current package of activities that have emerged as the U.S. research university will survive intact. The real disruptive force is the marketplace, brought onto campuses by new technologies in a highly competitive and disruptive fashion.

4. Bill Wulf (NAE) noted that past predictions of future social impacts from technological advance have been notably bad. They typically assume some version of the status quo, only faster, cheaper, bigger, etc. With today's technology, co-location is needed to help build and maintain trust.

That may not always be the case, with enough bandwidth. The most profound impact is from unanticipated, disruptive technologies (e.g. web browser or PDA).

5. After about an hour, Bob Berdahl stood up and said: "OK. Now you have convinced me. This technology is creating a future that is so uncertain that I don't have a clue how presidents can provide effective leadership. We need your help!"

Hence, we had managed to bring the group from denial to acceptance to seeking help!

The final session involved a discussion of how the National Academies (and various federal agencies) could help research universities respond to these challenges. Several of the priorities for next steps included:

(1) The Evolving Role of the President/Chancellor and the "Executive Core"

How can academic leaders help facilitate positive change on campus and help chart the institution's IT-mediated role in society in areas such as privacy and security, vibrancy and civility, and trust? How will this role change as campus boundaries become less well defined? Stuart Feldman suggested in post-summit discussions that it would be useful to move beyond the presidential focus to examine the role of the university's "executive core" of senior administrators.

(2) "Paying for the Revolution"

Shirley Jackson suggested that an analysis be undertaken of how the costs IT are developing on campuses, what the future prospects are, and how would they be paid for. This is an area where the Forum and other groups like AAU, EDUCAUSE, and NACUBO might explore a joint project or encourage a consulting company to do a pro bono survey.

(3) Assessing Educational Impacts

The need for more research into the impacts of IT, technology-enabled learning, was highlighted by a number of participants. This is an issue that affects education in general, not just research universities. NSF is launching a new Science of Learning Centers program, but what more should the Forum and other groups do?

(4) What Should Institutions Explore Doing Together?

It was noted several times during the discussion that successful collaboration in academia generally is conceived at the faculty level and then blessed by the administration. Internet2 is an example of institutions coming together for a common purpose. Are there other areas where collaboration should be explored?

(5) Global Education

Although the international dimensions of IT transformation of research universities were not extensively discussed, clearly IT holds the promise for academia to educate, perform research, and undertake outreach globally in ways that have not been possible up to now.

THE AAU PROVOSTS WORKSHOP – September 9, 2003

We had an opportunity to conduct a very similar workshop for the AAU provosts, following their September meeting in Newport Beach, California. This was organized very similarly to the Presidents' workshop, by first asking a panel of provosts to lay out the issues as they saw them at the moment, then to move the discussion to a longer-term perspective, and finally to conclude with a discussions of next steps.

It is probably not surprising that many of the near term issues raised by the provosts were very similar to those raised by the presidents:

Network and bandwith management
How do we pay for this technology
How do we protect security and privacy?
Data management and preservation issues

We then tried to bump the discussion up a notch to look at longer term issues such as:

The digital generation (students and faculty)
Cyberinfrastructure
Competition vs cooperation (OKI, OCW, etc.)
The instability of the current research university paradigm
The survival of the research university (an issue that would have been hard to put on the table with the university presidents)

Yet, again, probably not surprising, was a far greater degree of sophistication in understanding and addressing these issues.

And perhaps an even more significant difference: unlike the presidents, the provosts already recognized that these were very difficult issues, and they certainly didn't have the answers yet. This was also an interesting contrast with a quite similar workshop on technology held five years earlier when the provosts neither understood nor accepted the strategic nature of technology issues. Today it is clear that they have moved far beyond denial about the transformative nature of technology issues and are searching for effective strategies.

Some of the highlights of the discussion include:

1. There was a growing concern about the degree to which universities were being victimized by the effective monopolies created by providers such as

PeopleSoft, Blackboard, and, of course, Microsoft. As one provost put it, universities act like deer paralyzed in the oncoming headlights, continuing to re-invent the wheel and getting devoured by the marketplace. The provosts were essentially unanimous in their belief that it was time for the research universities to set aside their competitive instincts and to build consortia to develop together the technologies to support their instructional, research, and administrative needs through an open-source paradigm that would break the stranglehold of the current marketplace. Similar cooperation was needed in areas of cyberinfrastructure such as Internet2 and the National Lamba Rail.

2. Lloyd Armstrong (UCS) noted that universities are a fractal representation of broader society, and the imperatives of security and privacy in IT (and particularly the Internet) represented broader strategic issues for our world.

3. Many provosts suspected that while the faculty believed they knew how their students learned, in reality they didn't have a clue, particularly in technology-rich environments. Universities need far more sophisticated help (perhaps through NSF-sponsored programs) to understand the learning and cognitive processes, although the provosts also recognized the disruptive nature of these studies which might eliminate over time the rationale for the lecture-classroom paradigm.

4. The workshop concluded with a very broad ranging discussion concerning very fundamental issues such as the mission, roles, values, and traditions of the university. Susanne Lohmann reminded the group that during the 1865-1900 period, over a single generation American higher education changed essentially every one of its characteristics in a radical fashion, evolving from the colonial colleges to the Humboltian model of a research university, empowering the faculty, growing from institutions with hundreds to thousands of students, and through the land-grant movement, creating the new paradigm of the engaged public university.

Everything that could change, in fact, did change. Many in the workshop believed that we are well along in a similar period of dramatic change in higher education.

IT FORUM MEETING AT CARNEGIE MELLON ON "COGNITION, COMMUNICATION, AND COMMUNITIES" – September 5,6, 2003

To learn more about how learning occurs in technology-intensive environments, we held the September meeting of the IT Forum at Carnegie Mellon, famous both as one of the nation's most wired–and now wireless–campuses, and also for its extraordinary strength in the cognitive sciences.

As the faculty put it, their students these days are "electrified". They are a transformative force, and the CMU faculty simply reacts to this.

An example is the way students use this technology for communication. From instant messaging to e-mail to WiKi's to Blogs, students are in continual communication with one another, forming groups or entire communities that are always interacting, even in classes (as any faculty member who has been "Googled" can attest).

A second example: a young professor of physics told us he had been forced to give up trying to "teach" difficult concepts in his classes. Instead he introduces a topic by pointing to several resources until a few students in the class figure it out a way to teach themselves the concept. Then the teach their fellow students, and through peer-to-peer learning, the concepts propagates rapid through the class.

As Kevin Kelly put it, the CMU students are using instant messaging and googline to create their own learning environments. THEY will determine not only which learning technologies but as well which learning methods

work best. The faculty is reduced to catching up to formalize what the students have developed.

In fact, many CMU faculty have now concluded that perhaps the best approach is to turn the kids loose, to let information learning lead and shape formal learning in a way that responds to the great diversity in how students learn. Peer-to-peer learning is rapidly replacing faculty teaching as the dominant educational process on this technology-rich campus.

There is not yet a consensus among the faculty as to where they are headed, but there is strong agreement that IT is changing the learning process in very fundamental ways.

IT FORUM DISCUSSIONS ON LEARNING

Topic 1: The New Literacy

This technology is forcing us to rethink the nature of literacy.

From literacy in the oral tradition
To the written word
To the images of film and then television
To the computer and multimedia

But wait a minute, there are many other forms of literacy

Art, poetry, mathematics, (science itself)…

But more significantly, from literacy as "read only, listening, viewing" to composition in first rhetoric, then writing, and now in multimedia.

From another perspective, our society increasingly values not just analysis but synthesis, enabled by the extraordinary tools of the digital age.

Today, we have the capacity literally to create objects atom by atom. We are developing the capacity to create new life-forms through the tools of molecular biology and genetic engineering. And we are now creating new intellectual life-forms through artificial intelligence and virtual reality.

The professions that have dominated the late twentieth century—and to some degree, the late-twentieth century university—have been those that manage knowledge and wealth, professions such as law, business, and politics. Yet today there are signs that our society is increasingly valuing those activities that actually create new knowledge and wealth, professions such as art, music, architecture, and engineering. Perhaps the university of the twentieth century will also shift its intellectual focus and priority from the preservation or transmission of knowledge to the process of creation itself.

Increasingly, we realize that learning occurs not simply through study and contemplation but through the active discovery and application of knowledge. From John Dewey to Jean Piaget to Seymour Papert, we have ample evidence that most students learn best through inquiry-based or"constructionist" learning. As the ancient Chinese proverb suggests "I hear and I forget; I see and I remember; I do and I understand."

But herein lies a great challenge. While we are experienced in teaching the skills of analysis, we have far less understanding of the intellectual activities associated with creativity. In fact, the current disciplinary culture of our campuses sometimes discriminates against those who are truly creative, those who do not fit well into our stereotypes of students and faculty.

The university may need to reorganize itself quite differently, stressing forms of pedagogy and extracurricular experiences to nurture and teach the art and

skill of creation. This would probably imply a shift away from highly specialized disciplines and degree programs to programs placing more emphasis on integrating knowledge.

Perhaps it is time to integrate the educational mission of the university with the research and service activities of the faculty by ripping instruction out of the classroom–or at least the lecture hall–and placing it instead in the discovery environment of the laboratory or studio or the experiential environment of professional practice.

Topic 2: The Plug and Play Generation

The traditional classroom paradigm is being challenged today, not so much by professors, who have by and large optimized their teaching effort and their time commitments to a lecture format, but by our students. Members of today's digital generation of students have spent their early lives immersed in robust, visual, electronic media--Sesame Street, MTV, home computers, video games, cyberspace networks, MUDs and MOOS, and virtual reality.

Unlike those of us who were raised in an era of passive, broadcast media such as radio and television, today's students expect--indeed, demand--interaction. They approach learning as a "plug-and-play" experience. They are unaccustomed and unwilling to learn sequentially--to read the manual. Instead they are inclined to plunge in and learn through participation and experimentation. Although this type of learning is far different from the sequential, pyramidal approach of the traditional college curriculum, it may be far more effective for this generation, particularly when provided through a media-rich environment.

John Seely Brown and his colleagues at Xerox PARC have studied the learning habits of the plug-and-play generation and identified several interesting

characteristics of their learning process. First, today's students like to do several things at once–they "multitask", performing several tasks simultaneously at a computer such as website browsing and e-mail while listening to music or talking on a cellular phone. Although their attention span appears short, as they jump from one activity to another, they appear to learn just as effectively as earlier generations.

Furthermore, it is clear that they have mastered a broader range of literacy skills, augmenting traditional verbal communication skills with visual images and hypertext links. They are particularly adept at navigating through complex arrays of information, acquiring the knowledge resources they seek and building sophisticated networks of learning resources.

To be sure, for a time, such students may tolerate the linear, sequential lecture paradigm of the traditional college curriculum. They still read what we assign, write the required term papers, and pass our exams. But this is decidedly not the way they learn. They learn in a highly nonlinear fashion, by skipping from beginning to end and then back again, and by building peer groups of learners, by developing sophisticated learning networks in cyberspace. In a very real sense, they build their own learning environments that enable interactive, collaborative learning, whether we recognize and accommodate this or not.

However, their tolerance for the traditional classroom and four-year curriculum model may not last long. Students will increasingly demand new learning paradigms more suited to their learning styles and more appropriate to prepare them for a lifetime of learning and change

One can imagine the impact of millions of students from the digital generation as they seek the interactive, collaborative, and convenient learning experiences they have already experienced from other digital media. We should not underestimate the impact of the plug-and-play generation on the university.

After all, their use of digital technologies such as Napster and other peer-to-peer applications quickly overloaded our IT infrastructures and threatened the recording industry. Their use of the Net and other digital resources is already far more sophisticated than most faculty and staff. They will drive rapid and profound change in higher education since they will demand that we adapt the university to their learning needs and characteristics through market forces.

Topic 3: Learning Communities

From another perspective, what is really going on here is the formation of learning communities. In a sense, digital technology is useful because it supports new knieds of learning, knowledge-generating communities.

Why is this important to us? Because this is another form of community. Universities are instrinsically communities. IT is useful to the degree it supports learning, knowledge generating communities.

The learning process as rooted both in experience and social interaction. Learning requires the presence of communities.

This is the value of the university--to create learning communities and to introduce students into these communities.

Once we have realized that the core competency of the university is not simply transferring knowledge, but developing it within intricate and robust networks and communities, we realize that this is were the real impact of information technology occurs.

In true learning communities the distinction between teachers and students blurs. Both groups become active learners, working together to benefit each other.

What is next? Cyberinfrastructure that becomes functionally complete for specific knowledge communities. A merger of the real and virtual world. "Better than being there" experiences.

Do we need to think more systemically about "learning ecologies" that respond, adapt, and evolve? Is there any point at this early stage to begin to consider more comprehensive strategies? (Several believe absolutely!)

Key for institutions to provide a rich infrastructure where these ecologies can grow. Don't depend on the faculty to do this, however.

In these new learning paradigms, the word *student* becomes largely obsolete, because it describes the passive role of absorbing content selected and conveyed by teachers. Instead we should probably begin to refer to the clients of the twenty-first-century university as active *learners,* since they will increasingly demand responsibility for their own learning experiences and outcomes.

In a similar sense, the concept of a *teacher* as one who develops and presents knowledge to largely passive students may become obsolete. Today, faculty members who have become experts in certain subfields are expected to identify the key knowledge content for a course based on their area of interest, to organize and then present the material, generally in a lecture format, in this course.

More specifically, faculty members of the twenty-first-century university will find it necessary to set aside their roles as teachers and instead become designers of learning experiences, processes, and environments. In the process, tomorrow's faculty members may have to discard the present style of solitary learning experiences, in which students tend to learn primarily on their own through reading, writing, and problem solving. Instead, they may be asked to develop collective learning experiences in

which students work together and learn together, with the faculty member becoming more of a consultant or a coach than a teacher.

NSF TUTORIAL ON "TECHNOLOGY AND LEARNING" – October 29, 2003

We were invited to conduct a "conversation" with NSF leadership concerning the impact of technology on learning in an effort to help NSF-EHR, with the objective of:

1) Shape its agenda in these areas
2) Review ongoing activities (and investments)
3) Move from a focus on technology to broader cyberinfrastructure issues

From the perspective of resources, NSF-EHR represents a very substantial fraction of the federal investment in research and practice concerning education and learning (and most of the activity in science, mathematics, engineering, and technology). Yet EHR programs tend to be overly constrained—by tradition, by practice, and by Congress. As a consequence, EHR is NOT viewed by the scientific community as a place where innovative projects with high impact potential are conducted (or even tolerated). As a result, EHR has lost much of its opportunity for intellectual leadership to other programs within NSF (such as the new Science of Learning Centers, which will be primarily located in the research directorates) or other federal agencies (such as NIH). EHR faces a wide and broadening reality gap between what it is supposed to do and what it is able to accomplish, particularly in the eyes of the scientific community.

Perhaps we should begin with the simple question of what EHR sees as its mission and whether it believes its current portfolio of activities adequately addresses this mission? Does EHR have the will (and capacity)

to transform itself to address the needs of a changing world in the face of almost certain resistance from the scientific community, the education community, and Congress?

This is a particular challenge in critical areas such as the impact of rapidly evolving technology for learning and its implication for the STEM workforce. Hence the most important role of this conversation may be to put key questions before both EHR and NSF more generally that will break their thinking out of the box and encourage them to take a far more innovative approach to their programs.

Throughout its half-century-long history, NSF has stepped up from time to time as an important change agent to address major national priorities. The partnership between the federal government and higher education articulated in Vannevar Bush's Science, the Endless Frontier, created the American research university as we know it today. Much of the digital revolution in scientific research, education, and our broader society was stimulated by NSFnet and the resulting Internet. Today the human resource needs of the nation, an increasingly competitive global, knowledge-driven economy, and the challenge and promise presented by exponentially evolving digital technology presents a new and compelling challenge to NSF to provide leadership and stimulate change in our nation's learning enterprise.

<u>Some Specific Recommendations to EHR (and NSF)</u>

There is an urgent need to broaden the EHR portfolio far beyond its traditional programs, practices, and policies, all of which tend to constrain the directorate to funding the past rather than the future. We would recommend as alternatives efforts that involve:

Observation: Try to observe and understand <u>what is actually going on</u> (the behavior of the digital generation, what is really happening in

schools, colleges, what strategies learning institutions are taking, what is happening in informal learning).

Assessment: Encourage the development of rigorous assessment capability and provide both the necessary funding and assistance in grants to assess impact.

Action: EHR (and NSF) need to be far more activist, identifying critical tipping points for stimulating change and exploiting opportunities (e.g., the current testing-accountability environment or cyberinfrastructure initiatives)

Linkages: How does EHR link with the research directorates? How can NSF become more vascular.

Research Grants: EHR needs to redirect more of these away from "educators" and toward real scientists (meaning away from education schools and more toward the mainstream science and technology community).

A Sense of Urgency

It is important to stress the urgency of the human resource crisis facing the nation and the role that NSF-EHR could (should, indeed MUST) play in address this national priority.

- The turnover in the nation's K-12 teaching cadre will occur over the next 5 to 10 years. If substantial reform in teaching education and training is not accomplished soon, it will be a generation lost (of both teachers AND students).

- There is an urgent crisis in the availability of STEM human resources precipitated by the discontinuity in the flow of talented international

students to the United States as a consequence of the concerns about homeland security and global attitudes toward America in the aftermath of 9/11 and Iraq. This is a crisis of monumental importance to high-tech industries (not to mention research universities) in this country, and it should be high on the list of NSF priorities. Is it? Does the current portfolio of EHR activities address such issues? If not, why?

- New federal and state policies in testing and school accountability are driving a revolution at the K-12 level. This provides both a challenge and an opportunity to NSF: a challenge if teaching to the test dominates the student learning environment, and an opportunity if NSF were able to influence the testing and accountability process in STEM areas to enhance learning.

- Finally, the human resource implications of a global, knowledge-driven economy is driving massive change in the workforce education and training needs that must be addressed at all levels of the educational enterprise: K-12, higher education, postgraduate, workplace, and lifelong learning. Again this poses both a challenge and an opportunity for NSF.

Clearly time is not on the nation's side in addressing these multiple human resource challenges. The NSF needs to determine what it can accomplish in the near term with existing resources. But to do so, it needs to approach its current inventory of activities in a much more strategic and rigorous fashion and then make the necessary changes. It also must launch far bolder initiatives that anticipate a radically different future for learning and learning institutions.

In other words, NSF first needs to know what it knows. It then must transform itself into a learning institution capable of providing leadership, stimulating change, and responding to the needs of the nation.

IT FORUM ACTIVITIES FOR 2004

1. A Summit Meeting for Foundations (both private and government) exploring the way that IT might reconnect them to tapping the resources of the higher education community to address their key priorities (e.g., public health, poverty, global conflict).

2. Executive Leadership Core Workshops: A series of regional meetings involving the executive leadership core (president, provost, CFO, CIO, deans) of several universities comparing institutional strategies

3. IT Forum Meeting on Informal Learning (with a particular emphasis on entertainment and massively multiplayer games, e.g., "Harnessing the Hive")

Concluding Remarks

It is useful to summarize conclusions concerning the evolution of digital technology and its impact on the university.

First, we believe the extraordinary evolutionary pace of information technology is likely to continue for the next several decades and even could accelerate on a superexponential slope. The event horizons for disruptive change are moving ever closer. The challenge is getting people to think about the implications of accelerating technology learning curves as well as technology cost-performance curves is very important. There are likely to be major technology surprises, comparable in significance to the appearance of the personal computer in the 1970s and the Internet browser in 1994, but at more frequent intervals. The future is becoming less certain.

The impact of information technology on the university will likely be profound, rapid, and discontinuous--just as it has been and will continue to be for the economy, our society, and our social institutions (e.g., corporations, governments, and learning institutions). It will affect our activities (teaching, research, outreach), our organization (academic structure, faculty culture, financing and management), and the broader higher education enterprise as it evolves into a global knowledge and learning industry.

Yet, for at least the near term, meaning a decade or less, the university will continue to exist in much its present form, although meeting the challenge of emerging competitors in the marketplace will demand significant changes in how we teach, how we conduct scholarship, and how our institutions are financed. Universities must anticipate these forces, develop appropriate strategies, and make adequate investments if they are to prosper during this period.

Over the longer term, the basic character and structure of the university may be challenged by the IT-driven forces of aggregation (e.g., new alliances, restructuring of the academic marketplace into a global learning and knowledge industry) and disaggregation (e.g., restructuring of the academic disciplines, detachment of faculty and students from particular universities, decoupling of research and education).

Although we feel confident that information technology will continue its rapid evolution for the foreseeable future, it is far more difficult to predict the impact of this technology on human behavior and upon social institutions such as the university. It is important that higher education develop mechanisms to sense the changes that are being driven by information technology and to understand where these forces may drive the university. Because of the profound yet unpredictable impact of this technology, it is important that institutional strategies include : 1) the opportunity for experimentation, 2) the formation of alliances both with

other academic institutions as well as with for-profit and government organizations, and 3) the development of sufficient in-house expertise among the faculty and staff to track technological trends and assess various courses of action.

In summary, for the near term (meaning a decade or less), we anticipate that information technology will drive comprehensible if rapid, profound, and discontinuous change in the university. For the longer term (two decades and beyond), all bets are off. As we have noted implications of a million-fold increase in the power of information technology are difficult to even imagine, much less predict for our world and even more so for our institutions.

Although information technology will present many complex challenges and opportunities to university leaders, we suggest that procrastination and inaction are the most dangerous courses of all during a time of rapid technological change. After all, attempting to cling to the status quo is a decision in itself, perhaps of momentous consequence. To be sure, there are certain ancient values and traditions of the university that should be maintained and protected, such as academic freedom, a rational spirit of inquiry, and liberal learning. But, just as it has in earlier times, the university will have to transform itself once again to serve a radically changing world if it is to sustain these important values and roles.

Yet, while the challenges will be significant, so too will be the opportunities to enhance the important role of these institutions in our society.

University leaders should approach issues and decisions concerning information technology not as threats but rather as opportunities.

Creative, visionary leaders can tap the energy created by such threats to lead their institutions in new directions that will reinforce and enhance their most important roles and values.

They can use digital technology to help their students learn more effectively, to help their faculty members to become better teachers and scholars, to enable their institutions to better serve society.

It is our collective challenge as scholars, educators, and academic leaders to develop a strategic framework capable of understanding and shaping the impact that this extraordinary technology will have on our institutions.