The Future of the Research University in the Digital Age

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> "The impact of information technology will be even more radical than the harnessing of steam and electricity in the 19th century. Rather it will be more akin to the discovery of fire by early ancestors, since it will prepare the way for a revolutionary leap into a new age that will profoundly transform human culture."
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> —Jacques Attali, *Millennium* [1]

Introduction

Today our society and our social institutions are being reshaped by the rapid advances in information technology: computers, telecommunications, and networks. Modern digital technologies have increased vastly our capacity to know and to do things and to communicate and collaborate with others. They allow us to transmit information quickly and widely, linking distant places and diverse areas of endeavor in productive new ways. This technology allows us to form and sustain communities for work, play, and learning in ways unimaginable just a decade ago. Information technology changes the relationship between people and knowledge. And it is likely to reshape in profound ways knowledge-based institutions such as our colleges and universities.

Of course higher education has already experienced significant change driven by information technology. Our management and administrative processes are heavily dependent upon this technology, as the millions of dollars our institutions spent preparing for the date reset of Year 2000 made all too apparent. Research and scholarship depend heavily upon information technology, for example, the use of computers to simulate physical phenomena, networks to link investigators in virtual laboratories or "collaboratories," or digital libraries to provide scholars with access to knowledge resources. There is an increasing sense that new technology will also have a profound impact on teaching, freeing the classroom from the constraints of space and time and enriching the learning of our students through access to original materials.

Yet, while this technology has the capacity to enhance and enrich teaching and scholarship, it also poses certain threats to our colleges and universities. We can now use powerful computers and networks to deliver educational services to anyone, anyplace, anytime, no longer confined to the campus or the academic schedule. Technology is creating an open learning environment in which the student has evolved

into an active learner and consumer of educational services, stimulating the growth of powerful market forces that could dramatically reshape the higher education enterprise.

Today we are bombarded with news concerning the impact of information technology on the market place, from “e-commerce” to “edutainment” to “virtual universities” and “I-campuses”. The higher education marketplace has seen the entrance of hundreds of new competitors that depend heavily upon information technology. Examples include the University of Phoenix, the Caliber Learning Network, Sylvan Learning Systems, the Open University, the Western Governors University, and a growing array of “dot-coms” such as Unext.com and Blackboard.com. It is important to recognize that while many of these new competitors are quite different than traditional academic institutions, they are also quite sophisticated in their pedagogy, their instructional materials, and their production and marketing of educational services. They approach the market in a highly sophisticated manner, first moving into areas characterized by limited competition, unmet needs, and relatively low production costs, but then moving rapidly up the value chain to more sophisticated educational programs. These IT-based education providers are already becoming formidable competitors to traditional postsecondary institutions.

Some have even suggested that in the face of rapidly evolving technology and emerging competition, the very survival of the university, at least as we know it, may be at risk. Several recent quotes illustrate the concerns:

> “Thirty years from now the big university campuses will be relics. Universities won’t survive. It is as large a change as when we first for the printed book.” Peter Drucker, business sage

> “If you believe that an institution that has survived for a millennium cannot disappear in a just a few decades, just ask yourself what has happened to the family farm.” William Wulf, President of the National Academy of Engineering

> “I wonder at times if we are not like the dinosaurs, looking up at the sky at the approaching asteroid and wondering whether it has an implication for our future.” Frank Rhodes, President Emeritus, Cornell University

While most believe the university will survive the digital age, few deny that it could change dramatically in form and character. Knowledge is both a medium and a product of the university as a social institution. Hence it is reasonable to suspect that a technology that is expanding our ability to create, transfer, and apply knowledge by factors of 100 to 1,000 every decade will have a profound impact on the both the mission and the function of the university.

Clearly, the digital age poses many challenges and presents many opportunities for the contemporary university. For most of the history of higher education in America, we have expected students to travel to a physical place, a campus, to participate in a pedagogical process involving tightly integrated studies based mostly on lectures and seminars by recognized experts. As the constraints of time and space—and perhaps even reality itself—are relaxed by information technology, will the university as a physical place continue to hold its relevance?

More generally, are we entering just another period of evolution for the university? Or will the dramatic nature and compressed time scales characterizing the technology-driven changes of our time trigger a process more akin to revolution in higher education? Will a tidal wave of technological, economic, and social forces sweep over the academy, both transforming the university in unforeseen and perhaps unacceptable ways while creating new institutional forms to challenge both our experience and our concept of the university?

To address these questions, I have organized my speculative remarks into three layers. First I will discuss the impact of information on the fundamental activities of the university, teaching and scholarship. Next I will consider its impact on the structure and form of the university. Finally I would like to offer some observations concerning the impact on the broader post-secondary education enterprise.

However, before discussing the future of the university in the digital age, it seems appropriate to first provide–indeed, acknowledge–some background concerning my personal experience with this rapidly evolving technology. It is also useful to provide some background concerning how this technology is transforming our economy, our society, and our world.

A Personal Perspective

Let me begin with a personal caveat. Not only has my life essentially spanned that of the digital computer, but my particular area of study, nuclear energy, both stimulated and drove the development of this technology during much of its history.

- From mainframes to minicomputers to microcomputers
- From the IBM Stretch to CDC Star to Crays to ASCI
- From Ethernet to Arpanet to NSFnet to Internet to Internet2
- From key-punched cards to teletype terminals to graphical displays to GUIs to virtual reality CAVEs
- From batch processing to time-sharing to personal computing to client-server to distributed processing
- From the TRS 80 and Apple II to the IBM PC and Lisa to Pentium III and G-4s
- From desktops to laptops to personal digital assistants to ubiquitous computing
- From Unix to MS-DOS to Mac OS to Windows NT to Linux

All of my activities, from research to teaching, from administration to communication, have been influenced by this technology from the earliest days of my career. After all, the objects of my study, whether they were nuclear fission reactors or inertially confined thermonuclear fusion reactions or nuclear rocket engines, were hardly the phenomenon for laboratory study. Instead elaborate computer models were constructed to simulate such systems, relying on sophisticated mathematics, physics, and engineering concepts. Even the fundamental physics was simulated at the microscopic level using Monte Carlo methods or molecular dynamics simulations.

But beyond the science itself, my life as a scholar, teacher, and administrator was reshaped by each new “killer app”…

- e-mail
- wordprocessors
- spreadsheets
- symbolic mathematical tools such as Mathematica or Maple
- idea processors
- presentation software
- web browsers
- data warehouses and data mining
- net-based telephony and video streaming

Looking back over my 30 years as a faculty member and academic administrator, it is hard to imagine how I could have functioned without these tools. In fact, during my

transition from the presidency of the University back to the faculty, I was briefly trapped in a *virtual* state as the founding president of a new educational institution, the Michigan Virtual Automotive College, which rapidly morphed into the Michigan Virtual University[2] now serving thousands of students across our state. Hence, you can regard my speculations about the future of the university as those of one whose career roughly paralleled the evolution of this technology.

The Evolution of Information Technology

It is difficult to understand and appreciate just how rapidly information technology is evolving. Four decades ago, one of the earliest computers, ENIAC, stood 10 feet tall, stretched 80 feet wide, included more than 17,000 vacuum tubes, and weight about 30 tons. (We have 10% of ENIAC on display as an artifact in the lobby of the computer science department at Michigan.) Today you can buy a musical greeting card with a silicon chip more powerful than ENIAC. Already a modern $1,000 notebook computer has more computing horsepower than a $20 million supercomputer of the early 1990s. For the first several decades of the information age, the evolution of hardware technology followed the trajectory predicted by "Moore's Law"—that the chip density and consequent computing power for a given price doubles every eighteen months.[3] This corresponds to a hundredfold increase in computing speed, storage capacity, and network transmission rates every decade. . Of course, if information technology is to continue to evolve at such rates, we will likely need not only new technology but even new science. But with emerging technology such as quantum computing, molecular computers, and biocomputing, there is significant possibility that Moore's Law will continue to hold for at least a few more decades.

To put this statement in perspective, if information technology continues to evolve at its present rate, by the year 2020, the thousand-dollar notebook computer will have a computing speed of 1 million gigahertz, a memory of thousands of terabits, and linkages to networks at data transmission speeds of gigabits per second. Put another way, it will have a data processing and memory capacity roughly comparable to the human brain.[4] Except it will be so tiny as to be almost invisible, and it will communicate with billions of other computers through wireless technology.

This last comment raises an important issue. The most dramatic impact on our world today from information technology is not in the continuing increase in computing

power. It is in a dramatic increase in bandwidth, the rate at which we can transmit digital information. From the 300 bits-per-second modems of just a few years ago, we now routinely use 10-100 megabit-per-second local area networks in our offices and houses. Gigabit-per-second networks now provide the backbone communications to link local networks together, and with the rapid deployment of fiber optics cables and optical switching, terabit-per-second networks are just around the corner. Fiber optics cable is currently being installed throughout the world at the astounding equivalent rate of over 3,000 mph! In a sense, the price of data transport is becoming zero, and with rapid advances in photonic and wireless technology, telecommunications will continue to evolve very rapidly for the foreseeable future.

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 "peta" technology (one million-billion or 10^{15}). We will denominate the number of computer servers in the billions, digital sensors in the tens of billions, and software agents in the trillions. We will evolve from "e-commerce" and "e-government" and "e-learning" to "e-everything"!

More specifically, IBM estimates that by 2004 there will be over 1.3 billion net-enabled cellular phones or personal digital appliances (e.g., Palm Pilots) in the world. In fact, almost everyplace in the world will have robust wireless access to the Internet– except for the United States, where our continued reliance on traditional telephone networks and our archaic practices and regulations have limited the growth in wireless technology. Estimates are that by the end of the decade, the number of people linked into the Internet will surge to billions, a substantial fraction of the world's population, driven in part by the fact that most economic activity will be based on digital communication. By 2004 the size of the e-commerce economy is estimated to be over $6 trillion!

As a consequence, the nature of human interaction with the digital world—and with other humans through computer-mediated interactions—is evolving rapidly. We have moved beyond the simple text interactions of electronic mail and electronic conferencing to graphical-user interfaces (e.g., the Mac or Windows world) to voice to video. With the rapid development of sensors and robotic actuators, touch and action at a distance will soon be available. The world of the user is also increasing in sophistication, from the single dimension of text to the two-dimensional world of graphics to the three-dimensional world of simulation and role-playing. With virtual reality, it is

likely that we will soon communicate with one another through simulated environments, through “telepresence,” perhaps guiding our own software representations, our digital agents, our avatars, to interact in a virtual world with those of our colleagues.

This is a very important point. A communications technology that increases in power by 100-fold decade after decade will soon will allow human interaction with essentially any degree of fidelity we wish—3-D, multimedia, telepresence, perhaps even directly linking our neural networks into cyberspace, a la Neuromancer[5], a merging of carbon and silicon.

The Age of Knowledge

Looking back over history, one can identify certain periods of profound change in the nature, the fabric, of our civilization such as the Renaissance, the Age of Discovery, and the Industrial Revolution. There are many who contend that our society is once again undergoing such a fundamental shift in perspective and structure. The signs are all around us. We are evolving rapidly into a postindustrial, knowledge-based society, just as a century ago an agrarian America evolved into an industrial nation.[6] Today industrial production is steadily shifting from material- and labor-intensive products and processes to knowledge-intensive products. A radically new system for creating wealth has evolved that depends upon the creation and application of new knowledge.

We are in a transition period where intellectual capital, brainpower, is replacing financial and physical capital as the key to our strength, prosperity, and well being. In a very real sense, we are entering a new age, an *age of knowledge*, in which the key strategic resource necessary for prosperity has become knowledge itself, that is, educated people and their ideas.[7] As our society becomes ever more knowledge-intensive, it becomes ever more dependent upon those social institutions that create knowledge, that educate people, and that provide them with knowledge and learning resources throughout their lives.[8]

Our rapid evolution into a knowledge-based society has been driven in part by the emergence of powerful new information technologies such as computers, digital communications networks, multimedia, and virtual reality. Modern electronic technologies have increased vastly our capacity to know and to do things and to communicate and collaborate with others. They allow us to transmit information quickly

and widely, linking distant places and diverse areas of endeavor in productive new ways. We learn about events almost as they occur. The world has become linked electronically. This technology allows us to form and sustain communities for work, play, and learning in ways unimaginable just a decade ago.

Over the past several decades, computers have evolved into powerful information systems with high-speed connectivity to other systems throughout the world. Public and private networks permit voice, image, and data to be made instantaneously available across the world to wide audiences at low costs. The creation of virtual environments where human senses are exposed to artificially created sights, sounds, and feelings liberate us from restrictions set by the physical forces of the world in which we live. Close, empathic, multi-party relationships mediated by visual and aural digital communications systems are becoming common. They lead to the formation of closely bonded, widely dispersed communities of people interested in sharing new experiences and intellectual pursuits created within the human mind via sensory stimuli.

Unlike natural resources such iron and oil that have driven earlier economic transformations, knowledge is inexhaustible. The more it is used, the more it multiplies and expands. But knowledge is not available to all. It can be absorbed and applied only by the educated mind. Hence, schools in general and universities in particular will play increasingly important roles as our society enters this new age. The increasingly sophisticated labor market of a knowledge-driven economy is driving new needs for advanced education and training. Even today roughly two-thirds of America's high school graduates will pursue some form of college education, and this will likely increase as a college degree becomes the entry credential to the high-performance workplace in the years ahead. There is an increasingly strong correlation between the level of one's education and personal prosperity and quality of life. In a world in which knowledge and educated people have become the key to prosperity and security, there has been an increasing tendency for society to view the university as an engine for economic growth through the generation and application of new knowledge.

The Impact of Information Technology on the Activities of the University

The university has survived other periods of technology-driven social change with its basic structure and activities intact. But the changes driven by evolving information technology are different, since they affect the very nature of the fundamental activities of

the university: creating, preserving, integrating, transmitting, and applying knowledge. More fundamentally, because information technology changes the relationship between people and knowledge, it is likely to reshape in profound ways knowledge-based institutions such as the university.

There are several characteristics of information technology that set it apart from earlier experiences with technology-driven change:

- Its active rather than passive nature;
- The way that it obliterates the constraints of space and time (and perhaps
- reality);
- Its extraordinary rate of evolution, relentlessly increasing in power
- by factors of 100 to 1000 fold decade after decade; and
- The manner in which it unleashes the power of the market place.

Although it has been slower in coming, we are beginning to see the impact of technology on university teaching. Today's "digital generation" of students, media savvy, are demand new forms of pedagogy. They approach learning as a "plug-and-play" experience; they are unaccustomed and unwilling to learn sequentially—to read the manual—and instead 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. It challenges the faculty to design technology-rich experiences and environments based upon interactive, collaborative learning.

Sophisticated networks and software environments can be used to break the classroom loose from the constraints of space and time and make learning available to anyone, anyplace, at any time. The simplest approach uses multimedia technology via the Internet to enable distance learning. Yet many believe that effective computer-network-mediated learning will not be simply an Internet extension of correspondence or broadcast courses. Since learning requires the presence of communities, the key impact of information technology may be the development of computer-mediated communications and communities that are released from the constraints of space and time. There is already sufficient experience with such asynchronous learning networks to conclude that, at least for many subjects, the learning process is just as effective as

the classroom experience. There are presently for-profit entities[9] competing directly with traditional colleges and universities in the higher education marketplace through virtual university structures.

The attractiveness of computer-mediated distance learning is obvious for adult learners whose work or family obligations prevent attendance at conventional campuses. But perhaps more surprising is the degree to which many on-campus students are now using computer-based distance learning to augment their traditional education. Broadband digital networks can be used to enhance the multimedia capacity of hundreds of classrooms across campus and link them with campus residence halls and libraries. Electronic mail, teleconferencing, and collaboration technology is transforming our institutions from hierarchical, static organizations to networks of more dynamic and egalitarian communities. The most significant advantage of computer-mediated distant learning is access. Perhaps we should substitute "distributed" for "distance" learning, since the powerful new tools provided by information technology have the capacity to enrich all of education, stimulating us to rethink education from the perspective of the learner. The rich resources and new forms of social interaction enabled by information technology create the possibility of the objective of "better than being there" for distributed learning environments.

Distance learning based on computer-network-mediated paradigms allows universities to push their campus boundaries outward to serve learners anywhere, anytime. Those institutions willing and capable of building such learning networks will see their learning communities expand by an order of magnitude. In this sense, the traditional paradigm of "just-in-case" degree-based education can be more easily replaced by the "just in time" and "just-for-you" customized learning paradigms, more appropriate for a knowledge-driven society in which work and learning fuse together.

In the near term, at least, traditional models of education will coexist with new learning paradigms, providing a broader spectrum of learning opportunities in the years ahead. The transitions from student to learner, from teacher to designer/coach/consultant, and from alumnus to lifelong member of a learning community seem likely. And with these transitions and new options will come both an increasing ability and responsibility to select, design, and control the learning environment on the part of learners.

So, too, information technology is reshaping the nature of research. The earliest applications of information technology have been for solving mathematical problems in

science and technology. Today, problems that used to require the computational capacity of rooms of supercomputers can be tackled with contemporary laptop computer. The rapid evolution of this technology is enabling scholars to address previously unsolvable problems, e.g., proving the four-color conjecture in mathematics, analyzing molecules that have yet to be synthesized, or simulating the birth of the universe. The use of information technology to simulate natural phenomena has created a third modality of research, on par with theory and experimentation

New types of organizations are appearing that are based on evolving information technology. An example is be the "collaboratory" concept, an advanced, distributed infrastructure that uses multimedia information technology to relax the constraints on distance, time, and even reality. The process of creating new knowledge is evolving rapidly away from the solitary scholar to teams of scholars, often spread over a number of disciplines. This technology provides the tools to create, from desktop publishing to digital photography and video to creating objects atom-by-atom. There may even be a shift in knowledge production somewhat away from the analysis of what has been to the creation of what has never been—drawing more on the experience of the artist than upon analytical skills of the scholar.

The preservation of knowledge is one of the most rapidly changing functions of the university. The computer—or more precisely, the “digital convergence” of various media from print-to-graphics-to-sound-to-sensory experiences through virtual reality—will likely move beyond the printing press in its impact on knowledge. Throughout the centuries, the intellectual focal point of the university has been its library, its collection of written works preserving the knowledge of civilization. Today such knowledge exists in many forms—as text, graphics, sound, algorithms, and virtual reality simulations—and it exists almost literally in the ether, distributed in digital representations over worldwide networks, accessible by anyone, and certainly not the prerogative of the privileged few in academe.

The library is becoming less a collection house and more a center for knowledge navigation, a facilitator of information retrieval and dissemination.[10] In a sense, the library and the book are merging. One of the most profound changes will involve the evolution of software agents, collecting, organizing, relating, and summarizing knowledge on behalf of their human masters. Our capacity to reproduce and distribute digital information with perfect accuracy and with essentially zero cost has shaken the very foundations of copyright and patent law and threatens to redefine the nature of the

ownership of intellectual property. The legal and economic management of university intellectual property is rapidly becoming one of the most critical and complex issues facing higher education.

The Form and Function of the University

Colleges and universities are organized along intellectual lines, into schools and colleges, departments and programs, that have evolved over the decades (some would say largely following the structure of 19th Century science and literature rather than 21st Century knowledge). Furthermore, the governance, leadership, and management of the contemporary university are structured as well to reflect this intellectual organization as well as academic values of the university such as academic freedom and institutional autonomy rather than the command-communication-control administrative pyramid characterizing most organizations in business and government. The "contract" between members of the faculty and the university also reflects the unusual character of academic values and roles, the practice of tenure being perhaps the most visible example.

Yet we have suggested that information technology is already having great impact on the university. It has modified its fundamental activities of education, scholarship, and service to society quite significantly. Technology has created new channels of communication throughout the university and with broader society through mechanisms such as electronic mail and website conferences that largely bypass traditional administrative arrangement and external relationships. Technology has also completely transformed the manner in which information concerning the university, its people, and its activities is gathered, stored, and utilized.

Just as the university is challenged in adapting to new forms of teaching and research stimulated by rapidly evolving information technology, so too its organization, governance, management, and its relationships to students, faculty, and staff will require serious re-evaluation and almost certain change. For example, the new tools of scholarship and scholarly communication are eroding conventional disciplinary boundaries and extending the intellectual span, interests, and activities of faculty far beyond traditional organizational units such as departments or schools. This is particularly the case with younger faculty members whose interests and activities frequently cannot be characterized by traditional disciplinary terms.

Beyond driving a restructuring of the intellectual disciplines, information technology is likely to force a significant disaggregation of the university on both the horizontal (e.g., academic disciplines) and vertical (e.g., student services) scale. Faculty activity and even loyalty is increasingly associated with intellectual communities that extend across multiple institutions, frequently on a global scale. New providers are emerging that can far better handle many traditional university services, ranging from student housing to facilities management to health care. Colleges and universities will increasingly face the question of whether they should continue their full complement of activities or "outsource" some functions to lower cost and frequently higher quality providers.

It has become increasingly important that university planning and decision making not only take account of technological developments and challenges, but draw upon the expertise of people with technological expertise. Yet all too often, university leaders, governing boards, and even faculties ignore the rapid evolution of this technology, treating it more as science fiction than as a serious institutional challenge. To a degree this is not surprising, since in the early stages, new technologies sometimes look decidedly inferior to long-standing practices. For example, few would regard the current generation of computer-mediated distance learning programs as providing the socialization function associated with undergraduate education in a residential campus environment. Yet there have been countless instances of technologies, from personal computers to the Internet, that were characterized by technology learning curves far steeper than conventional practices. Such "disruptive technologies" have demonstrated the capacity to destroy entire industries, as the explosion of e-commerce makes all too apparent.

So, too, colleges and universities will need to reconsider a broad array of policies that have become antiquated in the digital age. Clearly those policies governing intellectual property, whether created through research or instructional activities, require a total overhaul. Traditional patent, copyright, and technology transfer policies make little sense in a world in which the digital products of intellectual activity can be reproduced an infinite number of times with perfect accuracy and at zero cost.[11]

Furthermore, the relationship between the university and its faculty, staff, and students needs to be reconsidered. The university will face a major challenge in retaining instructional "mindshare" among their best known faculty. Although we have long since adapted to the reality of those faculty getting released time and very

substantial freedom with regard to research activities, there will be new challenges as instructional content becomes a valuable commodity in a for-profit postsecondary education marketplace. Do we need new policies that restrict the faculty's ability to contract with outside organizations for instructional learningware. Can these policies be enforced in the highly competitive marketplace for our best faculty? Is it possible that we will see an unbundling of students and faculty from the university, with students acting more as mobile consumers, able to procure educational services from a highly competitive marketplace, and faculty members acting more as free-lance consultants, selling their services and their knowledge to the highest bidder?

In a sense, just as information technology has brought us to an inflection point in the nature of education and scholarship, it could also force us to redefine the relationship between the university and its teachers and students. Beyond this, we will face an ever mounting challenge in helping our faculties to keep pace with the extraordinary pace of technology evolution. In the old days we would wait for a generation of professors to pass on before an academic unit could evolve. In today's high-paced world, when the doubling time for technology evolution has collapsed to a year or less, we simply must look for effective ways to reskill our faculties or risk rapid obsolescence.

All universities face major challenges in keeping pace with the profound evolution of information and its implication for their activities. Not the least of these challenges is financial, since as a rule of thumb most organizations have found that staying abreast of this technology requires an annual investment of roughly 10 percent of their operating budget. For a very large campus such as the University of Michigan, this can amount to hundreds of millions of dollars per year!

But there are other challenges. Many universities are simply unprepared for the new plug-and-play generation, already experienced in using computers and net-savvy, who will expect—indeed, demand—sophisticated computing environments at college. More broadly, information technology is rapidly becoming a strategic asset for universities, critical to their academic mission and their administrative services, that must be provided on a robust basis to the entire faculty, staff, and student body.

In positioning itself for this technology, universities should recognize several facts of contemporary life. First, robust, high-speed networks are becoming not only available but also absolutely essential for knowledge-driven enterprises such as universities. Powerful computers are available at reasonable prices to students, but these will require a supporting network infrastructure. There will continue to be diversity in the technology

needs of faculty, with the most intensive needs likely to arise in parts of the university such as the arts and humanities where strong external support may not be available.

Historically, technology has been seen as a capital expenditure for universities or as an experimental tool to be made available to only a few. In the future, higher education should conceive of information technology both as an investment and a strategic asset that will be used by the entire faculty, staff, and study body to sustain and enhance the mission of the university. Colleges and universities must learn an important lesson from the business community: Investment in robust information technology represents the table stakes for survival in the age of knowledge. If you are not willing to invest in this technology, then you may as well accept being confined to a backwater in the knowledge economy, if you survive at all.

The Post-Secondary Education Enterprise

We generally think of higher education as public enterprise, shaped by public policy and actions to serve a civic purpose. Yet market forces also act on our colleges and universities. Society seeks services such as education and research. Academic institutions must compete for students, faculty, and resources. To be sure, the market is a strange one, heavily subsidized and shaped by public investment so that prices are always far less than true costs. Furthermore, if prices such as tuition are largely fictitious, even more so is much of the value of education services, based on myths and vague perceptions such as the importance of a college degree as a ticket to success or the prestige associated with certain institutions. Ironically, the public expects not only the range of choice that a market provides but also the subsidies that make the price of a public higher education less than the cost of its provision.

In the past, most colleges and universities served local or regional populations. While there was competition among institutions for students, faculty, and resources—at least in the United States—the extent to which institutions controlled the awarding of degrees, that is, credentialling, gave universities an effective monopoly over advanced education. However, today all of these market constraints are being challenged. The growth in the size and complexity of the postsecondary enterprise is creating an expanding array of students and educational providers. Information technology eliminates the barriers of space and time and new competitive forces such as virtual

universities and for-profit education providers enter the marketplace to challenge credentialling.[12]

The weakening influence of traditional regulations and the emergence of new competitive forces, driven by changing societal needs, economic realities, and technology, are likely to drive a massive restructuring of the higher education enterprise. From the experience with other restructured sectors of our economy such as health care, transportation, communications, and energy, we could expect to see a significant reorganization of higher education, complete with the mergers, acquisitions, new competitors, and new products and services that have characterized other economic transformations. More generally, we may well be seeing the early stages of the appearance of *a global knowledge and learning industry*, in which the activities of traditional academic institutions converge with other knowledge-intensive organizations such as telecommunications, entertainment, and information service companies.

Although traditional colleges and universities could play a role in such a technology-based, market-driven future, they could both threatened and reshaped by shifting societal needs, rapidly evolving technology, and aggressive for-profit entities and commercial forces. Together these could drive the higher education enterprise toward the mediocrity that has characterized other mass media markets such as television and journalism.

A key factor in this restructuring has been the emergence of new aggressive for-profit educator providers that are able to access the private capital markets (over $4 billion in the last year). Most of these new entrants such as the University of Phoenix and Jones International University are focusing on the adult education market Some, such as Unext.com, have aggressive growth strategies beginning first with addressing the needs for business education of corporate employees. Using online education, they are able to offer costs reductions of 60% or more over conventional corporate training programs since they avoid travel and employee time off. They are investing heavily (over $100 million in 2000) in developing sophisticated instructional content, pedagogy, and assessment measures, and they are likely to move up the learning curve to offer broader educational programs, both at the undergraduate level and in professional areas such as engineering and law. In a sense, therefore, the initial focus of new for-profit entrants on low-end adult education is misleading, since in five years or less their capacity to compete with traditional colleges and universities formidable indeed. We might think of traditional higher education as sunning itself on the beach in the warm

glow of a prosperous economy, unaware that the gentle surf lulling them to sleep is the precursor of a 100 foot tsunami of market forces beyond the horizon that could sweep over them before they can react or escape.

This perspective of a market-driven restructuring of higher education as a technology-intensive industry, while perhaps both alien and distasteful to the academy, is nevertheless an important framework for considering the future of the university. While the postsecondary education market may have complex cross-subsidies and numerous public misconceptions, it is nevertheless very real and demanding, with the capacity to reward those who can respond to rapid change and punish those who cannot. Universities will have to learn to cope with the competitive pressures of this marketplace while preserving the most important of their traditional values and character.

The market forces unleashed by technology and driven by increasing demand for higher education are very powerful. If allowed to dominate and reshape the higher education enterprise, we could well find ourselves facing a brave, new world in which some of the most important values and traditions of the university fall by the wayside. While the commercial, convenience-store model of the University of Phoenix may be a very effective way to meet the workplace skill needs of some adults, it certainly is not a paradigm that would be suitable for many of the higher purposes of the university. As we assess these market-driven emerging learning institutions, we must bear in mind the importance of preserving the ability of the university to serve a broader public purpose. While universities teach skills and convey knowledge, they also preserve and convey our cultural heritage from one generation to the next, perform the research necessary to generate new knowledge, serve as constructive social critics, and provide a broad array of knowledge-based services to our society, ranging from health care to technology transfer.

Furthermore, our experience with market-driven, media-based enterprises has not been altogether positive. The broadcasting and publication industries suggest that commercial concerns can lead to mediocrity, an intellectual wasteland in which the lowest common denominator of quality dominates. For example, although the campus will not disappear, the escalating costs of residential education could price this form of education beyond the range of all but the affluent, relegating much if not most of the population to low-cost (and perhaps low-quality) education via shopping mall learning centers or computer-mediated distance learning. In this dark, market-driven future, the

residential college campus could well become the gated community of the higher education enterprise, available only to the rich and privileged.

A contrasting and far brighter future is provided by the concept of a *society of learning*, in which universal or ubiquitous educational opportunities are provided to meet the broad and growing learning needs of our society. Today educated people and the knowledge they produce and utilize have become the keys to the economic prosperity and well-being of our society. Furthermore, one's education, knowledge, and skills have become primary determinants of one's personal standard of living, the quality of one's life.[13]

We are realizing that, just as our society has historically accepted the responsibility for providing needed services such as military security, health care, and transportation infrastructure in the past, today education has become a driving social need and societal responsibility. Today it has become the responsibility of democratic societies to provide their citizens with the education and training they need, throughout their lives, whenever, wherever, and however they desire it, at high quality and at an affordable cost.

Of course, this has been one of the great themes of higher education in America. Each evolutionary wave of higher education has aimed at educating a broader segment of society, at creating new educational forms to do that—the public universities, the land-grant universities, the normal and technical colleges, the community colleges.

So what would be the nature of a university of the twenty-first century capable of creating and sustaining a society of learning? It would be impractical and foolhardy to suggest one particular model. The great and ever-increasing diversity characterizing higher education in America makes it clear that there will be many forms, many types of institutions serving our society. But there are a number of themes that will almost certainly factor into at least some part of the higher education enterprise.

Just as other social institutions, our universities must become more focused on those we serve. We must transform ourselves from faculty-centered to learner-centered institutions, becoming more responsive to what our students need to learn rather than simply what our faculties wish to teach. Society will also demand that we become far more affordable, providing educational opportunities within the resources of all citizens. Whether this occurs through greater public subsidy or dramatic restructuring of the costs of higher education, it seems increasingly clear that our society—not to mention the

world—will no longer tolerate the high-cost, low-productivity paradigm that characterizes much of higher education in America today.

In an age of knowledge, the need for advanced education and skills will require both a personal willingness to continue to learn throughout life and a commitment on the part of our institutions to provide opportunities for lifelong learning. The concept of student and alumnus will merge. Our highly partitioned system of education will blend increasingly into a seamless web, in which primary and secondary education; undergraduate, graduate, and professional education; on-the-job training and continuing education; and lifelong enrichment become a continuum.

Already we see new forms of pedagogy: asynchronous (anytime, anyplace) learning that utilizes emerging information technology to break the constraints of time and space, making learning opportunities more compatible with lifestyles and career needs; and interactive and collaborative learning appropriate for the digital age, the plug-and-play generation. The great diversity characterizing higher education in America will continue, as it must to serve an increasingly diverse population with diverse needs and goals.

In a society of learning, people would be continually surrounded by, immersed in, and absorbed in learning experiences. Information technology has now provided us with a means to create learning environments throughout one's life. These environments are able not only to transcend the constraints of space and time, but using artificial intelligence and genetic algorithms they, like us, are capable as well of learning and evolving to serve our changing educational needs.

Here it seems appropriate at this point to make one further comment concerning “the digital divide”, the concern many have about a widening gap between those who can afford access to information technology and those who cannot. Such stratification in our society among the haves and have-nots would be of great concern if information technology were not evolving so rapidly. However, this technology is migrating rapidly toward “thin client” systems, in which the personal computer becomes an inexpensive and ubiquitous commodity available to anyone and everyone like today’s calculator or telephone, while the real investment occurs in the supporting network infrastructure.

In reality, the concern should not be with the digital divide, but rather with the growing gap in prosperity, power, and social well-being between those who have access to quality education and those who do not, because of economic circumstances, jobs, families, or location. From this perspective, the development of technology-based

methods for delivering educational services such as asynchronous learning networks and virtual universities may actually narrow the educational gap by providing universal access to quality educational opportunities. In a sense, computer networks might even be regarded as a for that will tend to "democratize" learning, since it will extend educational opportunities to those currently underserved by traditional colleges and universities.

The Challenge of University Leadership in the Digital Age

Today's college and university leaders face myriad important questions and decisions concerning the impact of information technology on their institutions. For example, they need to understand the degree to which this technology will transform their basic activities of teaching, research, and service. What will be the impact of this technology on the basic activities of the university, upon teaching and research? Will the classroom disappear? Will the residential campus experience of undergraduate education be overwhelmed by virtual universities or "edutainment." And what about the role that traditional forms of pedagogy will play in an increasingly online world? How should the university integrate information technology into its educational programs at the undergraduate, graduate, and professional school level? Will information technology alter the priorities among various university activities, e.g., the balance of educational activities related to socializing high school graduates compared to the rapid growth in the need for advanced education by adults in the high performance workplace?

What kind of information technology infrastructure will the university need? How will it finance the acquisition and maintenance of this technology? To what degree should an institution outsource the development and management of IT systems? How should the university approach its operations and management to best take advantage of this technology? How can institutions better link planning and decision making with likely technological developments and challenges? How can one provide students, faculty, and staff with the necessary training, support, and equipment to keep pace with the rapid evolution of information technology? What is the role of universities with respect to the "digital divide", the stratification of our society with respect to access to technology?

How do colleges and universities address the rapidly evolving commercial marketplace for educational services and content, including, in particular, the for-profit

and dot.com providers? What strategies and actions should colleges and universities consider? What kind of alliances are useful for colleges and universities in this rapidly changing environment? With other academic institutions? With business? On a regional, national, or global scale? Should colleges and universities join together to create a "best practices" organization that provides assistance in analyzing needs and opportunities?

How can colleges and universities grapple with the forces of disaggregation and aggregation associated with a technology-driven restructuring of the higher education enterprise? Will universities be forced to merge into larger units as the corporate world has experienced, or will they find it necessary to outsource or spinoff existing activities. Will more (or perhaps most) universities find themselves competing in a global marketplace, and how will that square with publicly supported universities? Will new learning lifeforms or ecologies evolve based upon information technology that will threaten the very existence of the university?

The list of questions and issues seems not only highly complex but overwhelming to university leaders, not to mention the state and federal governments that support higher education in America. Yet, surveys suggest that despite the profound nature of this issues, information technology usually does not rank high among the list of priorities for university planning and decision making.[14] Perhaps this is due to the limited experience most college and university leaders have with this emerging technology. It could also be a sign of indecisiveness and procrastination. Yet, as the pace of technological change continues to accelerate, indecision and inaction can be the most dangerous course of all.

A National Academy Project

Last year the National Academies (Science, Engineering, and Medicine) launched a major new study to explore the impact of information technology on the future of the research university, which I was asked to chair. The premise was that rapidly evolving information technology would pose great challenges and opportunities to higher education in general and the research university. Yet there was an increasing sense that many of the most significant issues were not yet well recognized or understand by either university leaders or federal research agencies.

To this end, a broad steering committee was established, comprised of leaders in the areas of information technology, higher education, and federal research policy:

Jim Duderstadt, Michigan (chair)
Dan Atkins, Michigan
John Seely Brown, Xerox PARC
Gerry Butters, Lucent
Marye Anne Fox, NCSU
Ralph Gomory, Sloan Foundation
Nils Hasselmo, AAU
Paul Horn, IBM
Shirley Jackson, RPI
Frank Rhodes, Cornell
Marshall Smith, Stanford
Lee Sproull, NYU
Doug Van Houweling, Internet2
Bob Weisbuch, Woodrow Wilson
Bill Wulf, NAE
Joe Wyatt, Vanderbilt
Tom Moss, NAS/GUIRR
Charlotte Kuh, NRC
Ray Fornes, NRC

The work of the committee has been proceeding along three fronts:

Technology Scenarios: What technologies are likely (possible) in the future (perhaps a 10 year planning horizon).

Implications for Research Universities: What are the implications of this evolving technology for the activities, organization, and enterprise of the research university?

Policies, Programs, Investments: What is the role, if any, for the federal government in protecting the valuable contributions of the research university in the face of these challenges?

Although we are less than a year into the study, the group has already arrived at several preliminary yet provocative conclusions:

1) There is no evidence of slowdown in the pace of IT evolution, by any measure or characteristic. In fact we appear to be on a superexponential technology learning curve that is likely to continue for at least the next several decades.
2) Photonic technology is evolving at twice the rate of silicon chip technology (e.g., Moore's Law), with miniaturization and wireless technology moving even faster, implying that the rate of growth of network appliances will be incredible.

3) 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).

3) There are likely to be major technology surprises, comparable in significance to the PC in 1980 and the Internet browser in 1994, but at more frequent intervals.

4) Getting people to think about the implications of accelerating technology learning curves as well as technology cost-performance curves is very important. The event horizons are much closer that most realize.

5) Most universities still look at IT as a cost, not as an investment with staggering cost benefits. If you are not going to invest in IT, you may as well get out of the game. Investment in robust information technology represents the table stakes for survival in the age of knowledge!

6) We need to distinguish between two time frames for the university:

A decade or less: Comprehensible if profound change

Two decades and beyond: All bets are off. (The “singularity”?)

We have scheduled a major conference in January at the National Academies that will bring together faculty leaders, academic administrators, and technologies to discuss the implications of our technology scenarios for the activities, organization, and function of the research university. Stay tuned.

The Future of the Research University in the Digital Age

As a primary source of basic research and the next generation of scholars and professionals, the research university will remain an institution of great value. In an age in which knowledge and educated people become a society’s most valuable resources, the research university has become ever more important as an intellectual force in our society. Today the research faculties in these institutions have become both the leaders and the arbiters of science and scholarship for the world. This group not only leads in knowledge production and distribution, but they have become the gatekeepers and standard-bearers, leading a complex knowledge system that both drives and sustains world education and learning. Furthermore, as highly educated scholars and professionals are increasingly sought as leaders in a knowledge-driven world, these institutions should continue to play a critical role.

Yet the broader higher education enterprise is changing rapidly–driven by changing social needs, powerful market force, and rapidly evolving technology–to serve a changing world. While the unique roles, the prestige, and the prosperity of the research university may allow it to defend the status quo for a time, this, too, will pose certain dangers. Furthermore, the research university is no longer seen as the top level of academic pecking order but instead as just one player in a broader higher education enterprise, where the priority will be educational services for a knowledge-driven society rather than specialized scholarship. To be sure, it would be both unrealistic and inappropriate for our research universities to abandon their critical roles in elite education and scholarship to become heavily involved in the universal education, the ubiquitous education, needed by our society. Furthermore, the market for educational services will be broad and diverse, and the brand name for exceptional quality characterizing these institutions will still carry considerable value.

Throughout most of history of higher education in America, these same institutions have been the leaders for the broader enterprise. They have provided the faculty, the pedagogy, the textbooks and scholarly materials, and the standards for all of higher education. They have maintained a strong relationship and relevance to the rest of the enterprise, even though they were set apart in role and mission. Yet, as the rest of the enterprise changes, there is a risk that if the research university becomes too reactionary and tenacious in its defense of the status quo, it could well find itself increasingly withdrawn and perhaps even irrelevant to the rest of higher education in America and throughout the world.

It is within this context of recognizing the unique mission and value of the research university even as we seek to preserve its relevance to the rest of higher education that we should examine several possible strategies for the future:

Isolation. Some of the most elite institutions may adopt a strategy of relying on their prestige and their prosperity to isolate themselves from change, to continue to do just what they have done in the past, and to be comfortable with their roles as niche players in the higher education enterprise. And this may be a very appropriate strategy for some unique institutions, places such as MIT, Caltech, Princeton, and Chicago. But for most of the larger and comprehensive institutions, the activities of elite education and basic research are simply too expensive to sustain without some attention to the marketplace.

Pathfinders. Perhaps a more constructive approach would be to apply the extraordinary intellectual resources of the research university to assist the broader higher education enterprise in its evolution to new learning forms. Although the research universities may not be appropriate for direct involvement in mass or universal education, they certainly are capable of providing the templates, the paradigms, that others could use. They have done this before in other areas such as health care, national defense, and the Internet. To play this role, the research university must be prepared to participate in experiments in creating possible futures for higher education.

Alliances. Extending this role somewhat, research universities might enter into alliances with other types of educational institutions, regional universities, liberal arts colleges, community colleges, or even newly emerging forms such as for-profit or cyberspace universities. This would allow them to respond to the changing needs of societies while remaining focused on their unique missions as research universities. One could also imagine forming alliances with organizations outside of higher education, for example, information technology, telecommunications, or entertainment companies, information services providers, or even government agencies.

Core-in-Cloud Models. Many research universities are already evolving into so-called “core in cloud” organizations,[15] in which academic departments or schools conducting elite education and basic research, are surrounded by a constellation of peri-university organizations—research institutes, think tanks, corporate R&D centers—that draw intellectual strength from the core university and provide important financial, human, and physical resources in return. Such a structure reflects the blurring of basic and applied research, education and training, the university and broader society.

More specifically, while the academic units at the core retain the traditional university culture of faculty appointments, for example, tenure, and intellectual traditions, for example, disciplinary focus, those peri-academic organizations evolving in the cloud can be far more flexible and adaptive. They can be multidisciplinary and project focused. They can be driven by entrepreneurial cultures and values. Unlike academic programs, they can come and go as the need and opportunity arise. And, although it is common to think of the cloud being situated quite close to the university core, in today’s world of emerging electronic and virtual communities, there is no reason why the cloud might not be widely distributed, involving organizations located far from the campus. In fact, as virtual universities become more common, there is no reason that the core itself has to have a geographical focus.

To some degree, the core-in-cloud model could revitalize core academic programs by stimulating new ideas and interactions. It can provide a bridge that allows the university to better serve society without compromising its core academic values. But, like the entrepreneurial university, it could also scatter and diffuse the activities of the university, creating a shopping mall character with little coherence.

The Darwinian World of Digital Technology

The digital age poses many challenges and opportunities for the contemporary university. For most of the history of higher education in America, we have expected students to travel to a physical place, a campus, to participate in a pedagogical process involving tightly integrated studies based mostly on lectures and seminars by recognized experts. Yet, as the constraints of time and space—and perhaps even reality itself—are relieved by information technology, will the university as a physical place continue to hold its relevance?

In the near term it seems likely that the university as a physical place, a community of scholars and a center of culture, will remain. Information technology will be used to augment and enrich the traditional activities of the university, in much their traditional forms. To be sure, the current arrangements of higher education may shift. For example, students may choose to distribute their college education among residential campuses, commuter colleges, and online or virtual universities. They may also assume more responsibility for and control over their education. In this sense, information technology is rapidly becoming a liberating force in our society, not only freeing us from the mental drudgery of routine tasks, but also linking us together in ways we never dreamed possible. Furthermore, the new knowledge media enables us to build and sustain new types of learning communities, free from the constraints of space and time. Higher education must define its relationship with these emerging possibilities in order to create a compelling vision for its future as it enters the next millennium.[16]

Although the digital age will provide a wealth of opportunities for the future, we must take great care not simply to extrapolate the past, but instead to examine the full range of possibilities for the future. There is clearly a need to explore new forms of learning and learning institutions that are capable of sensing and understanding the change and of engaging in the strategic processes necessary to adapt or control it.

No one knows what this profound alteration in the fabric of our world will mean, both for academic work and for our entire society. As William Mitchell, dean of architecture at MIT, stresses, "the information ecosystem is a ferociously Darwinian place that produces endless mutations and quickly weeds out those no longer able to adapt and compete. The real challenge is not the technology, but rather imagining and creating digitally mediated environments for the kinds of lives that we will want to lead and the sorts of communities that we will want to have."[17] It is vital that we begin to experiment with the new paradigms that this technology enables. Otherwise, we may find ourselves deciding how the technology will be used without really understanding the consequences of our decisions.

To be sure, information technology poses certain risks to the university. It will create strong incentives to standardize higher education, perhaps reducing it to its lowest common denominator of quality. It could dilute our intellectual resources and distribute them through unregulated agreements between faculty and electronic publishers. It will almost certainly open up the university to competition, both from other educational institutions as well as from the commercial sector. But it will also present extraordinary opportunities. Information technology is rapidly becoming a liberating force in our society, not only freeing us from the mental drudgery of routine tasks, but also linking us together in ways we never dreamed possible, overcoming the constraints of space and time. Furthermore, the new knowledge media enables us to build and sustain new types of learning communities, free from the constraints of space and time. This technology will democratize and distribute more broadly access to the unique resources of the university for teaching and scholarship.

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. We are on the threshold of a revolution that is making the world's accumulated information and knowledge accessible to individuals everywhere, a technology that will link us together into new communities never before possible or even imaginable. This has breathtaking implications for education, research, and learning and, of course, for the university in the digital age.

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