Navigating the American University
through the Stormy Seas of a Changing World

James J. Duderstadt

President Emeritus

University Professor of Science and Engineering

The University of Michigan

This past summer I had the opportunity to co-chair a four-day workshop in Switzerland concerning the future of the university. In attendance were roughly two dozen leaders of the world's leading universities from both North America and Europe, with the provocative assignment of imaging they had just received a no-strings-attached gift of $20 billion, with instructions to design from scratch a university for the 21st Century. Midway through our workshop, the Supreme Court handed down its decision on the Michigan affirmative action cases, an event of rather considerable interest both to me (as a named defendant) and to the American university presidents (and particularly Nils Hasselmo of AAU and David Ward of ACE). I'll return to comment more on this decision in a moment. But first back to the university futures workshop.

I thought it might be interesting if I drew on my Swiss experience, along some perspectives shaped by several national study groups I have recently chaired, to speculate a bit about the trends that will likely reshape, redirect, reinvent, and possibly even replace the university as we know it in the years ahead.

Of course when ever any group of university presidents get together, they usually begin with all the usual topics: money, students, politics, and, for an unfortunate few, intercollegiate athletics.

But I'm going to take a somewhat different approach, by climbing up to the 100,000 foot level, to look perhaps a decade or more ahead, with a view encompassing not simply higher education in the United States but throughout our increasingly interconnected world.

The Themes of Change in Higher Education

1. The Current Budget Crunch

Of course, foremost on the minds of most university leaders these days are the devastating cuts in appropriations as the states struggle to cope with crushing budget deficits or the erosion of private support from gifts and endowment income associated with a weak economy. Alan Merton, president at George Mason University has called this the "triple whammy of increasing

enrollments, declining state and philanthropic support, and rising expectations for higher education on the part of students and the broader public".

Of course, the optimist might suggest that this is just part of the ebb and flow of economic cycles. In bad times, state governments and donors cut support, hoping to restore it once again in good times. But this time it may be different. As one state budget officer noted: "College leaders are fooling themselves if they think the end of this recession will be like all the others. What we're seeing is a systematic, careless withdrawal of concern and support for advanced education in this country at exactly the wrong time."

Why the doom and gloom? In Europe and Asia, the erosion of public support is seen as a consequence of massification of higher education, in which tax revenues once supporting only university education for the elite are now being stretched beyond capacity to fund higher education for an appreciable fraction of the population.

In the United States, I would characterize our current dilemma somewhat differently as a transition from "guns" to "pills", as a nation, which once viewed education as critical to national security, seems today more concerned with sustaining the social benefits (and tax policies) demanded by an aging baby boomer population (and to hell with the kids). The priorities of those of us in this impacted wisdom group are clearly heath care, prisons, homeland security, and reduced tax burdens for the near term rather than in the education of the next generation and the future. This situation is unlikely to change until most of baby boomers in this room die off and allow our nation to re-establish an more appropriate balance between consuming for our present desires and investing for our children's future.

This is particularly important for the leaders of America's public universities. Today in the face of limited resources and more pressing social priorities, the century-long expansion of public support of higher education has slowed. While the needs of our society for advanced education can only intensify as we evolve into a knowledge-driven world culture, it is not evident that these needs will be met by further growth of our existing system of public universities.

We now have at least two decades of experience that would suggest that the states are simply not able—or willing—to provide the resources to sustain

growth in public higher education, at least at the rate experienced in the decades following World War II. In many parts of the nation, states will be hard pressed to even sustain the present capacity and quality of their institutions.

Most pessimistically, one might even conclude that America's great experiment of building world-class public universities supported primarily by tax dollars has come to an end. Put another way, the concept of a world-class, comprehensive state university might not be viable over the longer term, at least in terms of an institution heavily dependent upon state appropriations. It simply may not be possible to justify the level of tax support necessary to sustain the quality of these institutions in the face of other public priorities, such as health care, K-12 education, and public infrastructure needs—particularly during a time of slowly rising or stagnant economic activity.[1]

Yet there is a certain irony here, since society's dependence upon higher education in general and the research university in particular has never been stronger. Today we are evolving rapidly into a post-industrial, knowledge-based society, a shift in culture and technology as profound as the shift that took place a century ago when our agrarian societies evolved into industrial nations.

A radically new system for creating wealth has evolved that depends upon the creation and application of new knowledge. 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—educated people and their ideas (Bloch, 1988). Unlike natural resources, such as 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 can be created, absorbed, and applied only by the educated mind. Hence schools, in general, and universities in particular, will play increasingly important roles as our societies enter this new age.

And it is this reality of the global, knowledge-driven civilization of the 21st Century that is stimulating the powerful forces that will reshape the nature of our universities.

2. The Changing Higher Education Needs of Society

Today, a college degree has become a necessity for most careers, and graduate education desirable for an increasing number. A growing population will necessitate some growth in higher education to accommodate the projected increases in the number of traditional college age students, roughly 15% across the U.S. in the next decade, and considerably more in states such as California. But even more growth and adaptation will be needed to respond to the educational needs of adults as they seek to adapt to the needs of the high performance workplace. In fact, it is estimated that by 2010 over 50% of college students will be working adults over the age of 25!

Both young, digital-media savvy students and adult learners will likely demand a major shift in educational methods, away from passive classroom courses packaged into well-defined degree programs, and toward interactive, collaborative learning experiences, provided when and where the student needs the knowledge and skills.

The increased blurring of the various stages of learning throughout one's lifetime–K-12, undergraduate, graduate, professional, job training, career shifting, lifelong enrichment–will require a far greater coordination and perhaps even a merger of various elements of our national educational infrastructure. We are shifting from "just-in-case" education, based on degree-based programs early in one's life, to "just-in-time" education, where knowledge and skills are obtained during a career, to "just-for-you" educational services, customized to the needs of the student. The student is evolving into an active learner and eventually a demanding consumer of educational services.

This increasingly utilitarian view of higher education is reflected in public policy. Ask any governor about state priorities these days and you are likely to hear concerns expressed about education and workforce training. The National Governors Association notes that "The driving force behind the 21st Century economy is knowledge, and developing human capital is the best way to ensure prosperity."

Education is becoming a powerful political force. Just as the *space race* of the 1960s stimulated major investments in research and education, there are early signs that the *skills race* of the 21st Century may soon be recognized as the dominant domestic policy issue facing our nation. But there is an important

difference here. The space race galvanized public concern and concentrated national attention on educating "the best and brightest," the elite of our society. The skills race of the 21st Century will value instead the skills and knowledge of our entire workforce as a key to economic prosperity, national security, and social well-being.

3. Diversity

The increasing diversity of the American population with respect to race, ethnicity, gender and nationality is both one of our greatest strengths and most serious challenges as a nation. A diverse population gives us great vitality. However the challenge of increasing diversity is complicated by social and economic factors. Far from evolving toward one America, our society continues to be hindered by the segregation and non-assimilation of minority cultures. Our society is challenging in both the courts and through referendum long-accepted programs as affirmative action and equal opportunity aimed at expanding access to higher education to underrepresented communities and diversifying our campuses

Here, as many of you know, I speak with some personal involvement since I was a named defendant in two recent cases before the United States Supreme Court involving the University of Michigan's admissions. (I'm the *"et. al."* in the cases.). Although the Court split on these cases, the important feature of both opinions was the establishment that diversity in higher education is a compelling national interest, and that racial factors may play a role in efforts to achieve this objective.

At Michigan, we felt it was important that we "carry the water" for the rest of higher education to re-establish this important principle. Throughout our history, my university has been committed to providing, as one of our early presidents put it, "an uncommon education for the common man", being one of the first American universities to extend educational opportunities to the working class, to women, to racial and ethnic minorities, and to students from every state and nation.. We are absolutely convinced that there is a very strong linkage between academic excellence and campus diversity. Indeed, in an

increasingly diverse world, it is hard to imagine how the contemporary university can provide both a high quality and relevant education, not to mention contribute original scholarship and research, without reflecting such diversity among its students, faculty, and staff.

As a leader of society at large and a reflection of that society, the university has a unique responsibility to develop effective models of multicultural, pluralistic communities for our nation and our world. We must strive to achieve new levels of understanding, tolerance, and mutual fulfillment for peoples of diverse racial and cultural backgrounds both on our campuses and beyond. We need to shift our attention from simply access to educational opportunity to success in achieving educational objectives. The recent Supreme Court decisions have now not only reaffirmed the importance of this fundamental commitment, but the Court has also clarified the path we may take to achieve diversity in higher education. But we will still have many battles yet to fight before this war is won.

4. Technology

Several years ago the presidents of our National Academies launched a project to understand better the implications of information technology for the future of the research university, which I was asked to chair. Let me mention three key conclusions from first phase of this study:

> Point 1: The extraordinary evolutionary pace of information technology will not only continue for the foreseeable future, but it could well accelerate on a superexponential slope.

Digital technology is characterized by an exponential pace of evolution in which characteristics such computing speed, memory, and network transmission speeds for a given price increase by a factor of 100 to 1000 every decade. 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}). To illustrate with an extreme

example, if information technology continues to evolve at its present rate, by the year 2020, the thousand-dollar notebook computer will have a data processing speed and memory capacity roughly comparable to the human brain.[2] Except it will be so tiny as to be almost invisible, and it will communicate with billions of other computers through wireless technology.

For planning purposes, we can assume that by the end of the decade we will have available 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.

> Point 2: 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 is a *disruptive* technology (in the sense of Clayton Christenson).

Information and communications technology will affect the activities of the university (teaching, research, outreach), its organization (academic structure, faculty culture, financing and management), and the broader higher education enterprise. However, at least for the near term, meaning a decade or less, we believe the research 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.

Procrastination and inaction are the most dangerous courses for universities during a time of rapid technological change.

> Point 3: It is our belief that universities should begin the development of their strategies for technology-driven change with a firm understanding of those key values, missions, and roles that should be protected and preserved during a time of transformation.

6. Global Sustainability

Moving to a higher altitude to consider Planet Earth, like your president, I, too, am absolutely convinced that there is compelling evidence that the growing population and invasive activities of humankind are now altering the fragile balance of our planet. The concerns are both multiplying in number and intensifying in severity: the destruction of forests, wetlands, and other natural habitats by human activities leading to the extinction of millions of biological species and the loss of biodiversity; the buildup of greenhouse gases such as carbon dioxide and their possible impact on global climates; the pollution of our air, water, and land.

It could well be that coming to grips with the impact of our species on our planet, learning to live in a sustainable fashion on Spaceship Earth, will become the greatest challenge of all to our generation. We must find new ways to provide for a human society that presently has outstripped the limits of global sustainability.

This will be particularly difficult for the United States, a nation that has difficulty in looking more than a generation ahead, encumbered by a political process that generally functions on an election-by-election basis, as the current debate over global change makes all too apparent. With just 4.5% of the world's people, we control 25% of its wealth and produce 25% to 30% of its pollution. It is remarkable that the richest nation on earth is the lowest per capita donor of international development assistance of any industrialized country.

Ironically, the tragic events of September 11, 2001 might be viewed as a wake-up call, if we view these terrorist attacks not simply as a brief and brutal

criminal attack but rather the consequence of more fundamental causes. As the noted biologist Peter Raven put it in a recent address (Raven, 2002, p. 954-958):

> "The United States is a small part of a very large, poor, and rapidly changing world, and we, along with everyone else, must do a better job. Sustainability science has a good deal to say about how we can logically approach the challenges that await us, but the social dimensions of our relationships are also of fundamental importance. Globalization appears to have become an irresistible force, but we must make it participatory and humane to alleviate the suffering of the world's poorest people and the effective disenfranchisement of many of its nations. As many have stated in the context of the current world situation, the best defense against terrorism is an educated people. Education, which promises to each individual the opportunity to express their individual talents fully, is fundamental to building a peaceful world."

To be sure, the population of many developed nations today is aging rapidly. Over the next decade the percentage of the population over the age of 60 will grow from 15% to 20% to over 30% to 40% in the United States, Europe, and parts of Asia. Already we are feeling the consequences, as our national priorities increasingly focus on the concerns the elderly (e.g., health care) rather than the needs of the young (e.g., education). Yet on a global basis, half of the world's population is under the age of 20, with over two billion teenagers on Planet Earth, most living in Asia, Africa, and Latin America. Their demand for education will be staggering.

It is estimated that today are over 30 million people in the world who are fully qualified to enter a university but for whom no university place is available. Within a decade there will be 100 million university-ready people. Yet, as Sir John Daniels, former head of the British Open University notes, in most of the world, higher education is mired in a crisis of access, cost, and flexibility (Daniel, 1996). Unless we can address and solve this crisis, billions of people in coming generations will be denied the education so necessary to compete in, and survive in, an age of knowledge.

We must realize that the wealthy nations of the world have a particularly important role to play to assist developing nations in building the educational systems to meet their exploding needs. The university models characterizing most developed nations seem ill-suited to guiding us out of this global education crisis. Our colleges and universities continue to be focused on high-cost, low-technology, residential education and on the outmoded idea that quality in education is linked to exclusivity of access and extravagance of resources. Our current concept of the campus-based university could well deny higher education to nearly all of the billions of young people who will require it in the decades ahead.

7. Markets

The growing and changing nature of higher education needs will trigger strong economic forces. 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 our experience with other restructured sectors of the 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 <u>a global knowledge and learning industry</u>, in which the activities of traditional academic institutions converge with other knowledge-intensive organizations such as telecommunications, entertainment, and information service companies.[3]

Throughout the world we are moving toward a revenue-driven, market-responsive higher education system for two key reasons:

1. There is no way that a tax system can support the massification of higher education required by knowledge-driven economies, in the face of other compelling social priorities (particularly the needs of the aging).

2. The growing realization of the highly regressive nature of the conventional model of public higher education, with strong tax support and low tuition.

This situation is likely to continue for at least several decades, at least until a new generation restores a more appropriate balance between the consumption of an aging population and meeting the educational needs of the young. But as Zemsky reminds us, while it is relatively easy to start markets, it is very hard to stop them. We are at a tipping point in which resistance to market forces not longer yields resilience–instead the market will determine survival of the fittest. The market forces currently driving the evolution of higher education in the United States are global in extent, and they will sweep aside institutions dependent only upon public support. But there are warning signs.

Warning Sign 1: Darwinian Competition: Evidence of this increasingly market driven character of higher education is provided by the competition among universities. The arms race is escalating, as institutions compete ever more aggressively for better students, better faculty, government grants, private gifts, prestige, winning athletic programs, and commercial market dominance. This is aggravated by vast wealth accumulated by several of the elite private universities that allows them to buy "the best and brightest" students through generous financial aid programs (including merit-based programs) and raid outstanding faculty from less well-endowed institutions. The growing gap between faculty salaries characterizing private and public research universities have created a Darwinian ecosystem in which wealthy elite universities have become predators feeding on the faculties of their less well-endowed prey, causing immense damage to the quality of the latter's programs by luring away their top faculty with offers they are unable to match.

Warning Sign 2: Commercialization of the Academy: Yet another warning sign concerns the efforts of universities and faculty members to capture and exploit the soaring commercial value of the intellectual property created by research and instructional activities. This has infected the research university with the profit

objectives of a business, as both institutions and individual faculty members attempt to profit from the commercial value of the products of their research and instructional activities. Universities have adopted aggressive commercialization policies and invested heavily in technology transfer offices to encourage the development and ownership of intellectual property rather than its traditional open sharing with the broader scholarly community. They have hired teams of lawyers to defend their ownership of the intellectual property derived from their research and instruction. On occasions some institutions and faculty members have set aside the most fundamental values of the university, such as openness, academic freedom, and a willingness to challenge the status quo, in order to accommodate this growing commercial role of the research university.[4]

Warning Sign 3: From Public Good to Private Benefit: There is a deeper issue here. The American university has been seen as an important social institution, created by, supported by, and accountable to society at large. The key social principle sustaining the university has been the perception of education as a *public good*--that is, the university was established to benefit all of society. Like other institutions such as parks and police, it was felt that individual choice alone would not sustain an institution serving the broad range of society's education needs. Hence public policy dictated that the university merited broad support by all of society, rather than just by the individuals benefiting from its particular educational programs, through direct tax subsidy or indirect tax policies (e.g., treatment of charitable giving or endowment earnings).

Yet, today, even as the needs of our society for postsecondary education intensifies, we also find an erosion in the perception of education as a public good deserving of strong societal support.[5] State and federal programs have shifted from investment in the higher education enterprise (appropriations to institutions or students) to investment in the marketplace for higher education services (tax benefits to students and parents). Whether a deliberate or involuntary response to the tightening constraints and changing priorities for public funds, the new message is that education has become a private good that should be paid for by the individuals who benefit most directly, the students. Government policies that not only enable but intensify the capacity of

universities to capture and market the commercial value of the intellectual products of research and instruction represent additional steps down this slippery slope.

This shift from the perception of higher education as a public good to an individual benefit has another implication. To the degree that higher education was a public good, benefiting all (through sustaining democratic values, providing public services), one could justify its support through taxation of the entire population. But viewed as an individual benefit, public higher education is, in fact, a highly regressive social construct since, in essence, the poor subsidize the education of the rich, largely at the expense of their own opportunities.

Let me illustrate this with an example from my own university. For some time our state legislature has adopted a policy (at least in rhetoric) that state tax dollars should only be used to support Michigan residents. For that reason, the University of Michigan sets the tuition levels for nonresidents at essentially private university levels, $25,000 for 2003-2004, which also happen to be roughly our estimate of actual instructional costs for undergraduates. For Michigan residents, this tuition is discounted to $7,000. Our current state appropriation ($320 million) amounts to about $12,000 per Michigan student. Hence, you see that even if we were to apply the full appropriation to the subsidy of Michigan residents (ignoring the use of these funds for other state mandated activities such as public service, health care, etc.), this still leaves $25,000 – ($7,000 + $12,000) = $6,000 of the discount from actual costs to be covered from other sources. In reality, this funding gap must be covered from the same discretionary funds (from private gifts and endowment) we would use for student financial aid programs. The policy implications of this reality become even more apparent when it is noted that the average student family income at Michigan is now in excess of $100,000. It is clear that, at least for the University of Michigan, maintaining instate tuition levels far below the discount covered by state appropriations is coming at the expense of student financial aid. Put another way, low instate tuitions represent a very substantial subsidy of the costs of a college education for the affluent at the expense of the educational opportunities of those from less fortunate economic circumstances.

But even beyond this, if one views state support as providing essentially the discounted price from the true costs of the college education provided to state residents, one might well question why this should be distributed equally to all, rich and poor. If a fundamental objective of public higher education is access to educational opportunity, then a far more progressive social policy would be to distribute the state subsidy based on need, either through charging tuition prices closer to the true cost of an education and using state funding to provide need-based financial aid, or by setting tuition levels based on the ability to pay, with the consequent discount covered by state support–so-called high-tuition-high-financial-aid policies. The current low-tuition-low-financial aid policy in place in most states (and many nations) amounts to taxing the poor to subsidize the education of the rich.

The implications are that the marketplace coupled with a commitment to provide educational opportunities to all, regardless of economic ability, will increasingly drive many of the best public universities toward high-tuition, high financial aid policies in which state support becomes correctly viewed as a tax-supported discount of the price of education that should be more equitably distributed to those with true need. The leading public universities may increasingly resemble private universities in the way they are financed and managed. They will use their reputation, developed and sustained during earlier times of more generous state support, to attract the resources they need from federal and private sources to replace declining state appropriations. Put another way, many will embrace a strategy to become increasingly privately financed, even as they strive to retain their public character. Not that those public universities with the political capacity to move to high tuition will suffer, since the marketplace teaches us that high quality is frequently far more competitive than low cost (the Lexus sells better than the Neon!).

Warning Sign #4: The Loss of Public Purpose: In this process of responding to the market place by privatizing public higher education we could lose something of immense importance: the public purpose of the university. As Bob Zemsky stresses, markets are inexorable, and it is both fruitless and dangerous to pretend they are not. Yet, if they are allowed to dominate and reshape the higher

education enterprise without constrain, some of the most important values and traditions of the university will likely fall by the wayside. Will higher education retain its special role and responsibilities, its privileged position in our society? Will it continue to prepare young students for roles as responsible citizens? Will it provide social mobility through access to education? Will it challenge our society in the pursuit of truth and openness? Or will it become, both in perception and reality, just another interest group driven along by market forces? As we assess these market-driven emerging learning structures, we must bear in mind the importance of preserving the ability of the university to serve a broader public purpose.

A Word about the Special Situation of Public Higher Education

One obvious consequence of declining state support is that the several of the leading public universities may increasingly resemble private universities in the way they are financed and managed. They will move toward higher tuition-high financial aid strategies. They will use their reputation, developed and sustained during earlier times of more generous state support, to attract the resources they need from federal and private sources to replace declining state appropriations. Put another way, many will embrace a strategy to become increasingly privately financed, even as they strive to retain their public character. Not that those public universities with the political capacity to move to high tuition will suffer, since the marketplace teaches us that high quality is frequently far more competitive than low cost (the Lexus sells better than the Neon!).

The first wave of this "privatization" of support for public higher education started more than three decades ago, when public institutions began charging tuition as legislators cut back appropriations from tax dollars. It intensified with major fund-raising efforts and financial efforts such as spinning off operations such as medical centers and law and business schools.

Ironically–and perhaps not surprising in view of the nature of politics– even as public universities became less dependent on state support, state governments attempted to tighten the rains of state control with even more

regulations and bureaucracy in the name of "public accountability". Little wonder than in many states, public universities are now moving into a new phase of privatization by seeking to free themselves from state control since taxpayers now pay for such a small share of their overall operations. Little wonder that public university leaders are increasingly reluctant to cede control of their activities to state governments. Many institutions are even bargaining for more autonomy from state control as an alternative to growth in state support, arguing that if granted more control over their own destiny, they can better protect their capacity to serve the public.

Let me illustrate the point with a case study: Throughout much of the twentieth century the University of Michigan benefited from generous state support when a booming automobile industry made the Michigan economy unusually prosperous and a time when the University of Michigan was the only major university in the state. However by the 1970s, the energy crisis and foreign competition weakened Michigan's industrial economy. Furthermore, regional needs, ambitious leadership, and sympathetic political forces allowed a number of other public colleges in Michigan to grow into comprehensive universities, thereby competing directly with the University of Michigan for limited state appropriations.

During the 1950s and 1960s, almost 70 percent of the University's operating budget was provided through state appropriations from general tax revenues. However, over the past three decades, this has dropped to less than 10 percent of the University's total operating budget in the 1990s and less than 20 percent of its General and Education budget. During this period the University of Michigan evolved from "state-supported" to a "state-assisted" to a "state-related" to, today, what might be only characterized as a "state-located" university. Yet even this last identifier is questionable, since the University has campuses around the world, from Hong Kong to Seoul to Sao Paulo to Paris. In fact, the University has launched major new cyberspace "virtual" universities that have released it entirely from the constraints of geographical location. One of my colleagues suggested that University of Michigan today remains only a "state-molested" university, referring to the abuse it sometimes receives from opportunistic state politicians.

Perhaps a better way to phrase this is to observe that the University of Michigan has become, in effect, a privately-financed public university, supported by a broad array of constituencies at the national—indeed, international—level, albeit with a strong mission focused on state needs. Just as a private university, it must earn the majority of its support in the competitive marketplace (i.e., via tuition, research grants, and gifts). It allocates and manages its resources much as private universities. Yet it still retains a public character, committed to serving the people whose ancestors created it two centuries earlier.

It seems clear that the financial challenges to the public university require a serious rethinking and possibly even restructuring of all of its financial activities, from asset acquisition and allocation to financial management to cost containment.

- Universities need to explore new financial models that strive to build far more diversified funding portfolios, less dependent upon state appropriations, that enable public universities not only to increase the resources available for academic program support but moreover provide resilience against the inevitable ebb and flow of state support.

- Universities need to build adequate reserve capacity, both in the budgets of operating units and through endowment accounts.

- The allocation and management of resources, the containment of costs, and the adoption of efficiency measures common from business such as systems re-engineering and total quality management are important strategies

- But perhaps most significant is an entirely new approach to financial management, responsibility, and accountability that will enable the public university to thrive during a period of constrained public support.

- Public universities must break free those traditions that depend heavily upon generous state support, and instead manage their financial affairs much as private universities. They must become more entrepreneurial and proactive, seeking both the resources and the autonomy that will allow them to thrive in spite of the vicissitudes of public funding. In a sense, they must become privately financed and privately managed public universities.

Possible Futures of the University

A New Social Contract

Even more fundamentally, as we enter the new millennium, there is an increasing sense that the social contract between the university and American society may need to be reconsidered and perhaps even renegotiated once again.[6] Today we have entered an era in which educated people and the knowledge they produce and use have become the keys to the economic prosperity and social well-being. Moreover, education, knowledge, and skills have become primary determinants of one's personal standard of living. One might well argue that 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 that—the public universities, the land-grant universities, the normal and technical colleges, the community colleges, and today's emerging generation of cyberspace universities. But we now will need new types of colleges and universities with new characteristics:

1. Just as with 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.

2. 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.

3. 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.

4. 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.

5. 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. In a society of learning, people would be continually surrounded by, immersed in, and absorbed in learning experiences, i.e. ubiquitous learning, everywhere, every time, for everyone.

6. The great diversity characterizing higher education in America will continue, as it must to serve an increasingly diverse population with diverse needs and goals. But it has also become increasingly clear that we must strive to achieve

diversity within a new political context that will require new policies and practices.

It is clear that the access to advanced learning opportunities is not only becoming a more pervasive need, but it could well become a defining domestic policy issue for a knowledge-driven society. Higher education must define its relationship with these emerging possibilities in order to create a compelling vision for its future as it enters the new millennium

New Paradigms for the University

So what might we anticipate as possible future forms of the university? The monastic character of the ivory tower is certainly lost forever. Although there ar4e many important features of the campus environment that suggest that most universities will continue to exist as a place, at least for the near term, as digital technology makes it increasingly possible to emulate human interaction in all the sense with arbitrarily high fidelity, perhaps we should not bind teaching and scholarship too tightly to buildings and grounds. Certainly, both learning and scholarship will continue to depend heavily upon the existence of communities, since they are, after all, high social enterprises. Yet as these communities are increasingly global in extent, detached from the constraints of space and time, we should not assume that the scholarly communities of our times would necessarily dictate the future of our universities.

As illustrations, let me suggest several possible visions of the future, that progress ever more toward an unpredictable and unknowable future (and, as some might contend, toward the lunatic fringe…).

The Core-in-Cloud University: Many university communities are already evolving into so-called "core in cloud" organizations,[7] in which academic departments or schools conducting elite education and basic research, are surrounded by a constellation of quasi-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 quasi-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.

New Civic Lifeforms: Today, as knowledge becomes an ever more significant factor in determining both personal and societal well being, and as rapidly emerging information technology provides the capacity to build new types of communities, we might well see the appearance of new social structures.[8] A century ago, stimulated by the philanthropy of Andrew Carnegie, the public library became the focal point for community learning. Today, however, technology allows us to link together public and private resources such as schools, libraries, museums, hospitals, parks, media, and cultural resources. Further, communities can easily be linked with the knowledge resources of the world through the Internet. .

Perhaps a new "civic life form" will evolve to provide community education and knowledge networks that are open and available to all. These might evolve from existing institutions such as libraries or schools or universities. They might be a physically located hub or virtual in character. However, they also might appear as entirely new constructs, quite different than anything we have experienced to date. Perhaps it is time to consider a blank sheet approach to learning, by setting aside existing educational systems, policies, and practices, and instead first focusing on what knowledge, skills, and

abilities a person will need to lead a productive and satisfying life in the century ahead. Then, by considering the diversity of ways in which people learn, and the rich array of knowledge resources emerging in our society, designing a new ecology of learning for the 21st Century.

The University of the World…and in the World

An array of powerful economic, social, and technological forces are reshaping the very nature of the 21st century university. The emergence of a global, knowledge driven economy has intensified the need for broad access to advanced education and training (massification). The economic value of the knowledge produced by research universities continues to escalate. The rapid emergence of low-cost yet highly sophisticated technical services in large developing markets (e.g., India, China, Russia) has triggered a serious concern about the nature of university education necessary to sustain the high standard of living of wealthy economies. Yet, even in the face of such trends, the aging populations of many developed nations are depending increasingly on market forces and private funding rather than public policy and tax support to determine the future of their higher education systems.

Of particular interest is the way that such forces have stimulated a number of universities–and university organizations–to consider seriously expanding beyond the bounds of their nation-states to become universities both of the world and in the world, accepting a far broader responsibility to understand and serve both the social needs and marketplace of the global community.

Key in such strategies is the rapid evolution information, communication, and transportation technologies, which are enabling entirely new global learning and knowledge structures. The technologies are likely to enable a new species of research universities, both in and of the world, by achieving orders of magnitude shifts in the feasibility of many more people being in the knowledge communities of great research universities such as Michigan and Arizona State.

Some Lessons Learned

So, what are university planners to do, as their institutions are buffeted by such powerful forces of change, and in the face of unpredictable futures. Here, if I may, I would like to draw several lessons learned from the hard knocks of personal experience.

Values

It is important that any strategic effort always begin with the basics, by launching a careful reconsideration of the key roles and values that should be protected and preserved during a period of transformation. For example, how would an institution prioritize among roles such as educating the young (e.g., undergraduate education), preserving and transmitting our culture (e.g., libraries, visual and performing arts), basic research and scholarship, and serving as a responsible critic of society? Similarly, what are the most important values to protect? Clearly academic freedom, an openness to new ideas, a commitment to rigorous study, and an aspiration to the achievement of excellence would be on the list for most institutions. But what about values and practices such as shared governance and tenure? Should these be preserved? At what expense?

A Commitment to Excellence, but in an Increasingly Diverse Way

Of course, we all aspire to excellence, but just how do we set our goals? Frank Rhodes refers past several decades as the "Harvardization" of American higher education, in which the elite research universities became the gold standard, the model that other types of institutions, whether they be large public universities, private liberal arts colleges, or even regional and community colleges, attempted to emulate. But in the years ahead, Rhodes believes that we will see the de-Harvardization of higher education, as people begin to realize that an elite paradigm which simply focuses more and more resources on fewer and fewer does not serve the needs of American society.

Rather the premium will be on the development of unique missions for each of our institutions, missions that reflect not only their tradition and their

unique roles in serving society, but as well their core competency. As industry has learned, in an increasingly competitive global marketplace, you have to focus on what you can do best, where you are truly world-class, and outsource other products and services. This will require not only that each of our colleges and universities develop a unique vision, but beyond that, that they be prepared to focus resources to achieve it. They must be prepared to shift resources when necessary, possibly reducing or even eliminating some programs and activities in order to improve or initiate others. In such decisions, it must keep in mind the important criteria of quality, centrality, and cost-effectiveness.

Alliances

Universities should place far greater emphasis on building alliances with other institutions that will allow them to focus on core competencies while relying on alliances to address the broader and diverse needs of society. For example, flagship research universities in some states will be under great pressure to expand enrollments to address the expanding populations of college age students, possibly at the expense of their research and service missions. It might be far more constructive for these institutions to form close alliances with regional universities and community colleges to meet these growing demands for educational opportunity. Another example would be alliances between research universities and liberal arts colleges that take mutual advantage of the learning-intensive environment of the latter and the vast intellectual resources of the former.

Here alliances should be considered not only among institutions of higher education (e.g., partnering research universities with liberal arts colleges and community colleges) but also between higher education and the private sector (e.g., information technology and entertainment companies). Differentiation among institutions should be encouraged, while relying upon market forces rather than regulations to discourage duplication.

Experimentation

We must recognize the profound nature of the rapidly changing world faced by higher education. Many of the forces driving change are disruptive in nation, leading to quite unpredictable futures. Planning in the face of such uncertainty requires a more experimental approach to university transformation.

A personal example is useful here. During the 1990s we led an effort at the University of Michigan to transform the institution, to re-invent it so that it better served a rapidly changing world. We created a campus culture in which both excellence and innovation were our highest priorities. We restructured our finances so that Michigan became, in effect, a privately supported public university. We dramatically increased the diversity of our campus community. We launched major efforts to build a modern environment for teaching and research using the powerful tools of information technology.

Yet with each transformation step we took, with every project we launched, with each objective we achieved, we became increasingly uneasy. The forces driving change in our society and its institution were far stronger and more profound that we had first thought. Change was occurring far more rapidly that we had anticipated. The future was becoming less certain as the range of possibilities expanded to include more radical options. We came to the conclusion that in a world of such rapid and profound change, as we faced a future of such uncertainty, the most realistic near-term approach was to explore possible futures of the university through experimentation and discovery. That is, rather than continue to contemplate possibilities for the future through abstract study and debate, it seemed a more productive course to build several prototypes of future learning institutions as working experiments. In this way we could actively explore possible paths to the future. For example,

- We explored the possible future of becoming a privately supported but publicly committed university by completely restructuring our financing, raising over $1.4 billion in a major campaign, increasing tuition levels, dramatically increasing sponsored research support to #1 in the nation, and increasing our endowment ten-fold. Ironically, the more state support declined as a component of our revenue base (dropping to less than 10%

by the late 1990s), the higher our Wall Street credit rating, finally achieving the highest AAA rating (the first for a public university).

- Through a major strategic effort known as the Michigan Mandate, we altered very significantly the racial diversity of our students and faculty, doubling the population of underrepresented minority students and faculty over a decade, thereby providing a laboratory for exploring the themes of the "diverse university." (And ended up before the U.S. Supreme Court as a result.)

- We established campuses in Europe, Asia, and Latin America, linking them with robust information technology, to understand better the implications of becoming a "world university."

- We played leadership roles first in the building and management of the Internet and now Internet2 to explore the "cyberspace university" theme.

But, of course, not all of our experiments were successful. Some crashed in flames, in some cases spectacularly:

- We tried to spin off our academic health center, merging it with another large hospital system in Michigan to form an independent health care system. But our regents resisted this strongly, concerned that we would be giving away a valuable asset (even though we would have netted well over $1 billion in the transaction and avoided the $100 million annual operating losses we are now facing as managed care sweeps across Michigan.

- Although we were successful eventually in getting a Michigan Supreme Court ruling that provided relief from intrusive nature of the state's sunshine laws, we ran into a brick wall attempting to restructure how our governing board was selected and operated. (It remains one of the very

few in the nation still determined by popular election and partisan politics.)

- And we attempted to confront our own version of Tyrannosaurus Rex by challenging our Department of Athletics to better align their athletic activities with academic priorities, e.g. recruiting real students, reshaping competitive schedules, throttling back commercialism…and even appointing a real educator, a former dean, as athletic director. Yet today we are posed to spend $20 million on skyboxes for Michigan Stadium after expanding stadium capacity three years ago to over 110,000.

Nevertheless, in most of these cases, at least we learned something (if only our own ineffectiveness in dealing with cosmic forces such as college sports). More specifically, all of these efforts were driven by the grass-roots interests, abilities, and enthusiasm of faculty and students. While such an exploratory approach was disconcerting to some and frustrating to others, fortunately there were many on our campus and beyond who viewed this phase as an exciting adventure. And all of these initiatives were important in understanding better the possible futures facing our university. All have had influence on the evolution of our university.

Our approach as leaders of the institution was to encourage strongly a "let every flower bloom" philosophy, to respond to faculty and student proposals with "Wow! That sounds great! Let's see if we can work together to make it happen! And don't worry about the risk. If you don't fail from time to time, it is because you aren't aiming high enough!" We tried to ban the word "NO" from our administrators.

Turning Threats into Opportunities

It is important for university leaders to approach issues and decisions concerning transformation not as threats but rather as opportunities. True, the status quo is no longer an option. However, once we accept that change is

inevitable, we can use it as a strategic opportunity to control our destiny, while preserving the most important of our values and our traditions.

Creative, visionary leaders can tap the energy created by threats such as the emerging for-profit marketplace and technology to engage their campuses and to lead their institutions in new directions that will reinforce and enhance their most important roles and values.

One Final Lesson Learned

Oh, yes, there is one final lesson that I must share with you. Upon announcing my decision to return to the faculty after a decade of leading the university, one of my one of my vice-presidents slipped me a note with the well-known quote of Machiavelli:

> "There is no more delicate matter to take in hand, nor more dangerous to conduct, nor more doubtful of success, than to step up as a leader in the introduction of change. For he who innovates will have for his enemies all those who are well off under the existing order of things, and only lukewarm support in those who might be better off under the new."

After almost a decade of attempting to lead a transformational change process at the University of Michigan, I could only respond with an emphatic "AMEN!" The resistance can be intense, and the political backlash threatening.

To be sure, it is sometimes difficult to act for the future when the demands of the present can be so powerful and the traditions of the past so difficult to change. Yet, perhaps this is the greatest challenge for our institutions, and the most important role of our leadership, in the years ahead as we navigate our institutions through the stormy seas of a changing world.

Appendix

The Future of Engineering Education

Since my address today was at the invitation of Arizona State University's College of Engineering, it seems only appropriate that I add a few comments concerning the future of engineering education. Although it has been almost two decades since I last served as a dean of engineering, I still regard myself as an engineering faculty member, and, believe it or not, I do occasionally teach courses in engineering! But I also tend to be an heretic, absolutely convinced that engineering education as practiced today is in desperate need of a total overhaul.

In preparation for a talk on this subject, I recently had the opportunity to rummage a bit through the historical collections of my university to examine how engineering education was conducted a century ago. I was surprised to find out how similar the curriculum of that time was to today's programs. In 1900 we required students to take 130 credit hours of courses in mathematics, physics, and chemistry with a concentration in applied courses in areas such as mechanical, civil, and chemical engineering, just as we do today. In fact, if one swaps yesterday's requirement for surveying and mechanical drawing for today's courses on computers, the two curricula are almost identical. Of course, the actual content of these courses has changed considerably—or so one would hope.

With one major exception, the actual structure of the engineering curriculum has remained roughly the same over the past century. That exception is an important one. The 1900 curriculum placed far more stress on the importance of a liberal education, with more courses in humanities, arts, and social sciences. In fact, one might even suggest that we have regressed over the past century, overloading our current curriculum with highly specific technical courses at the expense of broader educational opportunities for our students.

Of course, engineering practice today is dramatically different than it was a century ago. Indeed, it is quite different from that of two decades ago, when most of our current faculty members were educated. This raises an important

question: Is the education we provide today for technical professions such as engineering adequately preparing our students for a world of practice and citizenship that is quite different from the one that we have known?

Study after study has suggested that dramatic change is necessary in engineering education. From the National Academies to federal agencies such as the National Science Foundation to industrial groups to accreditation agencies there is a growing consensus that engineering education today remains trapped in a mid-20th Century paradigm[9] (or perhaps even a late 19th Century paradigm, if my archeological discoveries about similarity between early engineering curricula and today's offerings are correct). We continue to provide a form of engineering education, which, while familiar from our own educational experiences, is increasingly irrelevant to the changing needs of a profession—not to mention a society—that is already far beyond our universities.

The context for considering the nature of undergraduate education in general and engineering education in particular is provided by the broader challenges of change characterizing our world and impacting higher education. Engineering education will not be exempt from these changes, but may be swept along at the crest of the wave of university change. Put another way, I believe there is little likelihood that the engineering curriculum will continue to preserve its century-old structure in the century—indeed, in the decade—ahead.

The Challenges

Today, engineering practice is evolving rapidly in response to a rapidly changing world. The shifting nature of national priorities from defense to economic competitiveness, the impact of rapidly evolving information technology, the use of new materials and biological processes—all have had deep impact on engineering practice. Put another way, the shift of our society from guns to butter, from transportation to communication, from atoms to bits, means that today's engineering students will spend most of their careers coping with challenges and opportunities vastly different from those most currently practicing engineers—or currently teaching faculty—have experienced. While engineers are expected to be well grounded in the fundamentals of science and

mathematics, they are increasingly expected to acquire skills in communication, teamwork, adaptation to change, and social and environmental consciousness.

It is also clear from this perspective that engineering education simply has not kept pace with this changing environment. It is only a slight exaggeration to say that our students are currently being prepared to practice engineering in a world that existed when we, as their faculty, were trained a generation or two ago. They are not being prepared for the 21st Century.

No doubt that part of this challenge is due to the intellectual organization of the contemporary university in which academic programs are partitioned into increasingly specialized and fragmented disciplines. Perhaps reflecting the startling success of science in the 20th Century, most disciplines are reductionist in nature, focusing teaching and scholarship on increasingly narrow and specialized topics. While this produces graduates of great technical depth, it is at a certain sacrifice of a broader, more integrated education. This is particularly true in science-based disciplines such as engineering. The old saying is not far off the mark, "A Harvard graduate knows absolutely nothing about absolutely everything. An MIT graduate knows absolutely everything about absolutely nothing!"

We must question the value of narrow specialization at a time when engineering practice and engineering systems are becoming large, more complex, and involving components and processes from widely dispersed fields. Many believe that the most important intellectual problems of our time will not be addressed through disciplinary specialization but rather through approaches capable of integrating many different areas of knowledge—through "big think" rather than "small think".

Ironically enough, the essence of engineering practice is the process of integrating knowledge to some purpose. Unlike the specialized analysis characterizing scientific inquiry, engineers are expected to be society's master integrators, working across many different disciplines and fields, making the connections that will lead to deeper insights and more creative solutions, and getting things done. Thus, engineering education is under increasing pressure to shift away from specialization to a more comprehensive curriculum and broader educational experience in which topics are better connected and integrated.

As the knowledge base in most engineering fields continues to increase at an ever more rapid rate, the engineering curriculum has become bloated with technical material, much of it already obsolete. Most undergraduate engineering programs have already become almost five years in length for most students. Even with this increasing technical content, most engineers will spend many months if not years in further workplace training before they are ready for practice. Furthermore, the effort to include the new technical knowledge in many fields, while retaining as well much of the old, has squeezed out other important curriculum content in areas. For example, at the University of Michigan, the humanities and social sciences component of the undergraduate curriculum has dropped to less than twenty credit hours, with as low as two credit hours of free electives in some engineering majors.

We simply have to accept the fact that it is no longer possible (if it ever was) for an engineering student to learn all they need to know during their undergraduate studies. Acquiring the array of technical knowledge and experience is a lifetime goal and requires a personal commitment to continual learning. An undergraduate engineering education should be viewed as only the initial launch for a career, designed to place the student in a lifetime orbit of learning.

As the growth of technical knowledge accelerates and the undergraduate engineering curriculum becomes more bloated and strained with new technical content, it becomes ever more apparent that it is simply no longer possible to regard the baccalaureate degree as sufficient for professional practice. Today, engineering is one of the very few professions that require only an undergraduate degree for professional status. Most other knowledge-intensive professions such as law, medicine, and even business, utilize graduate programs built upon a diversity of undergraduate majors. Little wonder that the status of engineers lag somewhat behind those of other professionals with more advanced education.

The inadequacy of the baccalaureate degree for professional practice is becoming apparent to employers as well. There is an increasing trend to hire graduates at the masters or even Ph.D. level for technical work, while relying upon baccalaureate engineering graduates for supporting services such as sales

and technical support. Although study after study has recommended that the masters degree become the accepted route into the engineering practice, this continues to be resisted both by the profession and the academy.

There is little doubt that the current sequential approach to engineering education, in which the early years are dominated by science and mathematics courses with engineering content deferred to the upper-class years, discourages many capable students. Students have little opportunity to find out what engineering is all about until late in their undergraduate studies. It is not unusual to find students wandering into our counseling and placement offices in their senior year, still trying to find out what they are majoring in and what they can do with an engineering degree. Compounding this is the fragmentation of the current curriculum, consisting of highly specialized and generally unconnected and uncoordinated courses, whose relationship to one another and to engineering education is rarely explained. Although everyone agrees that the undergraduate curriculum should focus on the fundamentals, few can agree on just what content is truly fundamental.

While the rigor of the scientific and mathematics foundation of modern engineering is important, it must be augmented by the broader contextual and integrative approach characterizing engineering practice. Students must gain experience not only in solitary analysis but also in group work and hands-on "design-build-operate" projects. We must strive to integrate real design and process understanding into the educational system. Above all, we must challenge our students to think, to create, and to understand excellence.

In today's world of change, most graduates will find themselves frequently changing not only jobs, but entire careers. We already find that only about fifty percent of engineering graduates will enter technical careers, and after five years, about half of these will have moved into other areas such as management or sales. Put another way, most engineering graduates of today will find themselves in engineering practice for only a relatively short period, if at all.

Yet the increasing importance of technology to our world has made an engineering degree an excellent preparation for many other careers and professions: business, law, medicine, consulting, and government service, to

name only a few. This poses a particular challenge to engineering educators, since they still focus primarily on educating students for the engineering profession.

Instead, as Roland Schmitt, former chair of the National Science Board and president of RPI has noted, we must enlarge the very concept of the engineer to cover a wider range of human activities than every before. Engineering educators must begin by realizing that it is their duty to educate the leaders of our society as well as to educate the professional engineer. We should develop and promote a new kind of engineering education as a form of "liberal education" for the 21st Century. This will require new objectives and new curricula, some radically different that those of today because of a radically different objective: educating not simply professional engineers but a new breed of graduates with an engineering-based, liberal education.

Engineering faculties are almost unique among those of professional schools since they generally have little experience or activity in professional practice. The strong research focus of most engineering schools has led to a cadre of strong engineering scientists, able at generating new knowledge but relatively inexperienced in professional practice. Furthermore, engineering faculty are judged and rewarded by criteria appropriate to science faculty. Indeed, professional practice is not only absent in promotion and reward criteria, but frequently discouraged. The faculty reward system recognizes teaching, research, and service to the profession, but it gives little recognition for developing a marketable product or process or designing an enduring piece of the nation's infrastructure.

It would be hard to imagine a medical school faculty comprised only of biological scientists rather than practicing physicians or music school faculty comprised only of musicologists rather than performing artists. Yet such detachment from professional practice and experience is the norm in engineering education.

It Is Time for Stop Talking and Take Action

Engineering educators, professional societies, and federal funding agencies such as the National Science Foundation have not been insensitive to these concerns. All agree that sea change in engineering education would require a concurrent change from the predominant engineering school academic culture based on compartmentalization of knowledge, individual specialization, and a research-based reward structure to one that values integration as well as specialization, teamwork as well as individual achievement, and educational research and innovation as well as research in the engineering sciences. These studies suggested a new set of goals for engineering education:

- To offer a broad liberal education that provides the diversity and breadth needed for engineering
- To prepare graduates for entry into careers and further study in both the engineering and nonengineering marketplace
- To develop the motivation, capability, and knowledge base for lifelong learning

This will require a very major change in the engineering curriculum. To some degree, it will require modernizing the science and mathematics instruction, e.g., recognizing that discrete rather than continuous mathematics is the foundation of the digital age, that biology and chemistry are rapidly becoming more important than physics, that new materials and processes have made obsolete much of the traditional curriculum. Beyond these technical changes, the NSF studies recognized that the new engineering curriculum must reflect a broad range of concerns, including environmental, political, social, international, and legal and ethical ramifications of decisions. Although the technical component would continue to be the core of an engineering education,

the economic, political, social, and environmental context of engineering practice needs to be explicitly addressed.

Beyond that, engineering education should move away from the current dominance of classroom-based pedagogy to more active learning approaches that engage problem-solving skills and team building. Joseph Bordogna, Deputy Director of the National Science Foundation and a former engineering dean recalls the old Chinese proverb:

> I hear and I forget.
> I see and I remember.
> I do and I understand. [10]

This is apt indeed for engineering education. As a recent NSF workshop put it, the ubiquitous lecture is the bane of true learning, especially in observation-based, hands-on fields such as engineering. The lecture-dominated system encourages a passive learning environment, a highly compartmentalized (lecture-sized) curriculum, and worst of all, instills neither the motivation nor the skills for life-long learning. The dependence on the standard lecture must be diminished with emphasis given instead to discovery-oriented learning. We must create discovery-oriented learning environments that capitalize on the full power of new communication, information, and visualization technologies."

Undergraduate engineering programs can no longer ignore the fact that they simply cannot provide all the necessary knowledge for graduates to remain competitive throughout their careers. Content-based learning alone must not drive engineering education. The primary aim should be instead to instill a strong knowledge of how to learn, while still producing competent engineers who are well grounded in engineering science and mathematics and have an understanding of design in the social context. Engineering schools must educate the student for a lifetime of learning rather than just for their initial job. Students must learn how to learn, and they must be able to assess their skills and educational needs throughout their many careers. As Peter Drucker puts it, "We are redefining what it means to be an educated person. Traditionally an educated person was someone who had a prescribed stock of formal knowledge.

Increasingly an educated person will be someone who has learned how to learn and who continues to learn throughout his or her lifetime."

Despite this broad effort, change in engineering education has been modest, as reflected in the tone of frustration in the recent remarks of Bill Wulf, President of the National Academy of Engineering: "We have studied engineering reform to death. While there are differences among the reports, the differences are not great. Let's get on with it! It is urgent that we do!"

Who is holding back change? Professional societies and accreditation agencies such as ABET? No, we have seen that they have become important forces of change.

What about industry? To be sure there is still a good deal of myopia among the recruiters that visit our placement office, all too often reinforcing very narrow definitions of student majors and abilities. Yet at high levels of management, there is strong awareness of the need for a broader form of engineering education. In a recent survey of CEOs conducted by the Business Higher Education Forum, it was found that the qualities valued most highly in graduates were not specific technical knowledge or skills but rather the ability to communication clearly, a commitment to lifelong learning, the ability to adapt to an increasingly diverse world, and finally the willingness not only to adapt to change but to actually drive it.

What about the faculty itself? To be sure, change is sometimes a four-letter word on university campuses. It is sometimes said that universities change one grave at a time. Judging from my comparison of the engineering curriculum of a century ago, even this may be too optimistic for engineering education. In fact, engineering educators do tend to be very conservative with regard to pedagogy, curriculum, and institutional attitudes. This conservatism produces a degree of stability (perhaps inflexibility is a more apt term) that results in a relatively slow response to external pressures.

For the past several decades, the emphasis of engineering education has been focused on the scientific foundation of engineering knowledge. In part this had to do with the impact of modern science on technology. But it was also due to the culture of the research university, in which engineering faculty were evaluated based on their performance in fundamental research rather than

engineering practice. Many believe this emphasis on research has also eroded the quality of teaching in engineering schools. In fact, a recent conference of young faculty suggested that most engineering schools not only fail to support adequately but also outright discourage faculty achievements in teaching, instructional scholarship, and public service. Tenure and promotion criteria do not encourage faculty to aspire to broad scholarly achievements, especially innovation, nor to contributions to public understanding.

Some Ideas for Accelerating Change

In the spirit of stimulating debate and thought, let me suggest a few more Draconian actions designed both to shake up and transform engineering education. First, it may be time to start with a clean slate by eliminating all specialized engineering majors, particularly at the undergraduate level. The ever more narrow specialization among engineering majors is driven largely by the reductionist approach of scientific analysis rather than the highly integrative character of engineering synthesis. It may be appropriate for basic research, but it is certainly not conducive to the education of contemporary engineers nor to engineering practice. Although students may be stereotyped by faculty and academic programs—and perhaps even campus recruiters—as electrical engineers, aerospace engineers, etc., they rapidly lose this distinction in engineering practice. Today's contemporary engineer must span an array of fields, such as modern technology, systems, and processes.

Perhaps it is time to go even further and simply abandon the concept of an undergraduate engineering major and instead provide a general engineering curriculum, much as in other professions such as medicine, law, and business. Like these professions, one could leave specialization until later, provided either through graduate study or on-the-job training.

In fact, one might conjecture that in a future characterized by lifelong learning, perhaps engineering will rapidly evolve along the lines of other learned professions and shift professional education and training entirely to the graduate level, eliminating the undergraduate engineering degree altogether. There are strong reasons to suspect that a broad, liberal education is just as important for

engineering practice as it is for other professions such as medicine and law. (Here one could also make the case for significantly greater technical and scientific content in the contemporary liberal arts curriculum.)

Although science and engineering are heavily based on laboratory methods, in fact they are usually taught through classroom lectures coupled with problem-solving exercises. Contemporary engineering education stresses the analytic approach to solving well-defined problems so familiar from science and mathematics—not surprising, since so many engineering faculty members received their basic training in science rather than engineering. To be sure, design projects required for accreditation of engineering degree programs are introduced into advanced courses at the upper-class level. Yet design and synthesis are quite small components in most engineering programs.

Clearly those intellectual activities associated with engineering design—problem formulation, creativity, innovation—should be introduced throughout the curriculum. This will require a sharp departure from classroom pedagogy and solitary learning methods. Beyond team design projects, engineering educators might consider adopting the case method approaches characterizing business and law education. More use might be made of internships as a formal part of the engineering curriculum, whether in industry or perhaps even in the research laboratories of engineering faculty where engineering design is a common task.

It is absolutely essential to broaden the engineering faculty to include practitioners. One approach would be to work with industry to persuade and allow senior engineering staff to accept faculty appointments. In fact, many retired engineers would make ideal faculty members, bringing their wealth of experience in engineering practice not only to the students but to the reshaping of the current science-driven culture of engineering schools. Of course, this would require a very significant restructuring of the faculty promotion and reward systems. It might even lead to the elimination of tenure, at least in some components of engineering education. But the mix of practitioners and scholars has been both accepted and constructive in most other professional schools—medicine, law, business, architecture, and the fine arts. It seems high time to bring engineering education into line.

As we noted earlier, engineering educators should be challenged to devise an engineering-based "liberal education" for students of the 21ˢᵗ Century. Engineering principles and modes of thought should be the centerpiece of what the liberally educated person should know in the age of knowledge that is our future. We should produce graduates for all careers—from industry to law to government—with an education attuned to the issues and challenges of a knowledge-driven society, many of which have dominant technical themes. The old saying that the purpose of a college education is not to prepare a student for their first job but rather their last job still has a ring of truth.

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[1] Joseph L. Dionne and Thomas Kean, *Breaking the Social Contract: The Fiscal Crisis in Higher Education,* Report of the Commission on National Investment in Higher Education (New York: Council for Aid to Education,1997).

[2] Ray Kurzweil, *The Age of Spiritual Machines: When Computers Exceed Human Intelligence* (New York: Viking, 1999).

[3] Marvin W. Peterson and David D. Dill, "Understanding the Competitive Environment of the Postsecondary Knowledge Industry", in Planning and Management for a Changing Environment, edited by Marvin W. Peterson, David D. Dill, and Lisa A. Mets (San Francisco: Jossey-Bass Publishers, 1997) pp. 3-29.

[4] Eyal Press and Jennifer Washburn, "The Kept University", *The Atlantic Monthly*, March, 2000, pp. 39-54.

[5] Robert Zemsky, "Rumbling," *Policy Perspectives*, Pew Higher Education Roundtable, sponsored by the Pew Charitable Trusts (Philadelphia: Institute for Research on Higher Education, April 1997).

[6] Vernon Ehlers, "Unlocking Our Future: Toward a New National Science Policy," a report to Congress by the House Committee on Science (September 24, 1998).

20. "Inside the Knowledge Factory," *The Economist* (October 4, 1997); See also Michael Gibbons, *The New Production of Knowledge* (London: Sage, 1994).

[8]. *Buildings, Books, and Bytes: Libraries and Communities in the Digital Age* (Washington, D.C.: Benton Foundation, 1996), Funded by the W. R. Kellogg Foundation.

[9] Morgan, Robert P., Proctor P. Reid, Wm. A. Wulf, "The Changing Nature of Engineering", ASEE Prism, May-June, 1998, pp. 13-17.

[10] Bordogna, Joseph, Eli Fromm, Edward W. Ernst, "Engineering Education: Innovation Through Integration", *Journal of Engineering Education*, January, 1993, pp. 38.