Introduction

UGa as ==first state university== in America
- But, while UGa was incorporated in 1785, it actually didn't hold its first classes until 1801; UNC was founded in 1789, but it began instruction in 1795.

- Although Harvard claims to be first in 1632, actually the Virginia Company founded a university near Jamestown in 1618, although it was wiped out in the Indian Massacre of 1622, only to reappear as ==William and Mary in 1693.==

Despite being a ==has-been president==, I do find myself invited from time to time to met again with university leadership groups, using as a =="professional 2x4".==
- ==AAU== and ==NASULGC==
- E==UA== (Barcelona) and ==U Vienna Dies Academicus==
- ==Spellings== Commission and ==Miller Center==
- ==Knight Commission==? (20 Years of "==Progess=="???)

Now of course whenever any group of university leaders get together, the discussions always begin with the usual topics:

- ==money,==
- ==students,==
- ==politics,==
- ==and for the unfortunate few, intercollegiate athletics.==

My ==assigned topic== this morning is:

=="Some Observations on the 21s Century University and a Changing World"==

My Challenge: Things are changing so rapidly that much of what I describe is likely to have changed yet again before I fly back to Ann Arbor this weekend!

In fact, I think the best approach is to break this discussion into three different timeframes:

- Now! Or at least within a few months!!!
- Soon! Within a few years!
- Eventually! Within our lifetimes–and certain those of our students!!!

Along the way I'll make a few observations about the implications this for flagship research universities such as the University of Georgia and the role that programs in engineering should play–indeed, MUST play–in its future.

Let me begin with a few datapoints:

- Last year Harvard announced that its endowment had risen to $37 billion, while Stanford set a new record for annual gifts at $832 million. Three months later Harvard's endowment had lost roughly $10 billion in value; Stanford had lost $5 billion, and both institutions were planning to reduce expenditures by 15% or greater, as were several other of the wealthiest private universities, whose operations had become heavily dependent on the income from long-term endowment investments of limited liquidity. In fact, Harvard has had to borrow $2.5 billion in high interest, taxable bonds just to maintain its operations this year.

- As the global recession has deepened, state after state began to project tax revenue declines and warn their public universities of deep budget cuts in the range up to 20% to 30%. This is on top of two decades of eroding tax support of public universities as the states have struggled with the burdens of aging populations.

- In Georgia serious consideration is being given to throttling back the HOPE scholarship program as lottery revenues flatten and tuitions rise. (In Michigan, the legislature has proposed eliminating our similar Michigan Promise scholarship entirely, although frankly we have been encouraging them to shift from merit- to need-based aid for years).

- The University of California has already begun to implement 20% cuts over two years, with 8% salary decreases, payless furlough days, and ramping up employee contributions to retirement and health care plans. But a cultural problem: UCSD proposal to close UCM, UCSC, and UCR; faculty/student walkout last week. They don't know how to cope with lifeboat exercises, where eventually someone has to be tossed overboard or the boat will sink.

- Actually, this decline in public support was nothing new for my university, located in the Rust Belt close to Detroit and the

collapsing American automobile industry. Over the past 30 years we had seen our public support decline from 70% of our operating budget to less than 6%. We now expect to lose another 20% over the next two years, dropping our state support to less than 4% of our operating budget. As university president I used to explain that during this period we had evolved from a state-supported to a state-assisted to a state-related to a state-located university. In fact, with campuses in Europe and Asia, we remained only a state-molested institution.

- And, on a more personal note, most faculty members of American universities do not have pensions for retirement–rather we participate in "defined contribution" retirement programs that contribute every year to personal accounts invested in the stock market. Hence most of us have lost 30% or more of our retirement savings over the last several months. Fortunately, since we do not have mandatory retirement ages in the United States, we can continue to work, although we may never recover enough assets to afford retirement.

- Even more serious is the possibility that impact of the collapse of faculty retirement accounts and consequent decisions to remain long after normal retirement age could eliminate the availability of positions opening up for the recruitment of new, younger faculty and the intellectual renewal of our universities.

Even though we are seeing early signs of recovery (let's just hope it isn't a "dead cat bounce", there remain serious challenges:

- The deep budget cuts now faced by our public universities come on the heels of over two decades of eroding public support as aging populations stress other social priorities such as retirement security, health care, safety from crime, and tax relief. It is also clear that in the current deep economic recession, there will be strong public and political pressure to resist efforts to increase tuition levels to mitigate the impact of such funding cuts.

- For private universities, endowments heavily dependent upon long-term, ill-liquid assets have taken big hits (30% or greater) causing temporary declines in operating revenues for the wealthiest institutions. However many of these universities were spending several times the amount per student as public institutions, over $100,000 per student per year in some case, and will likely come out of the recession taking advantage of low prices for new investments and hence widening the resource gap between richly endowed private universities and state supported public universities even further.

While the more optimistic among us may prefer to focus on opportunities that sometime arise in a crisis–the yang in the yin–it is also the case that such traumatic stresses can reveal flaws in the system, as I will suggest later.

But let me first broaden both the discussion and the timescale a bit and review some of the near-term challenges facing higher education from a global perspective.

Today our world has entered a period of rapid and profound economic, social, and political transformation based upon a emerging new system for creating wealth that depends upon the creation and application of new knowledge and hence upon educated people and their ideas.

- It has become increasingly apparent that the strength, prosperity, and welfare of a nation in a global knowledge economy will demand a highly educated citizenry enabled by development of a strong system of tertiary education.

- It will also require institutions with the ability to discover new knowledge, develop innovative applications of these discoveries, and transfer them into the marketplace through entrepreneurial activities.

It is this reality of the hyper-competitive, global, knowledge-driven economy of the 21st Century that is stimulating the powerful forces that will reshape the nature of our society and that pose such a formidable challenge to our nation and our states and cities.

- Today, a college degree has become a necessity for most careers, and graduate education is desirable for an increasing number. In the knowledge economy, the key asset driving corporate value is no longer physical capital or unskilled labor.

- Instead it is intellectual and human capital. This increasingly utilitarian view of higher education is reflected in public policy. 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." (NGA, 2004)

- 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 academically elite of our society. The <u>skills race</u> of the 21st Century will value instead the skills and knowledge of most of our workforce as a key to economic prosperity, national security, and social well-being.

- As Tom Friedman stresses in his provocative book, *The World is Flat*, "The playing field is being leveled. Some three billion people who were out of the game have walked and often have run onto a level playing field, from China, India, Russia, and Central Europe, from nations with rich educational heritages. The flattening of the world is moving ahead apace, and nothing is going to stop it. What can happen is a decline in our standard of living if more Americans are not empowered and educated to participate in a world where all the knowledge centers are being connected. We have within our society all the ingredients for American individuals to thrive in such a world, but if we squander these ingredients, we will stagnate." (Friedman, 2005).

Yet the traditional institutions responsible for advanced education and research–colleges, universities, research institutes–are being challenged by the powerful forces characterizing the global economy: demographic change, increasing ethnic and cultural diversity, hypercompetitive markets, and disruptive technologies such as information, biological, and nanotechnologies.

Demographics

The populations of most developed nations in North America, Europe, and Asia are aging rapidly. In our nation today there are already more people over the age of 65 than teenagers, and this situation will continue for decades to come. Over the next decade the percentage of the population

over 60 will grow to over 30% to 40% in the United States, and this aging population will increasingly shift social priorities to the needs and desires of the elderly (e.g., retirement security, health care, safety from crime and terrorism, and tax relief) rather than investing in the future through education and innovation.

However, the United States stands apart from the aging populations of Europe and Asia for one very important reason: our openness to immigration. In fact, over the past decade, immigration from Latin America and Asia contributed 53% of the growth in the United States population, exceeding that provided by births (National Information Center, 2006). This is expected to drive continued growth in our population from 300 million today to over 450 million by 2050, augmenting our aging population and stimulating productivity with new and young workers.

- As it has been so many times in its past, America is once again becoming a nation of immigrants, benefiting greatly from their energy, talents, and hope, even as such mobility changes the ethnic character of our nation. By the year 2030 current projections suggest that approximately 40% of Americans will be members of minority groups; by mid-century we will cease to have any single majority ethnic group.

- By any measure, we are evolving rapidly into a truly multicultural society with a remarkable cultural, racial, and ethnic diversity. This demographic revolution is taking place within the context of the continuing globalization of the world's economy and society that requires Americans to interact with people from every country of the world.

Diversity

The increasing diversity of the American population with respect to culture, race, ethnicity, 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.

- Today, far from evolving toward one America, our society continues to be hindered by the segregation and non-assimilation of minority and immigrant cultures. If we do not create a nation that mobilizes the talents of all of our citizens, we are destined for a diminished role in the global community and increased social turbulence.

- Higher education plays an important role both in identifying and developing this talent. Yet many are challenging in both the courts and through referenda long-accepted programs such as affirmative action and equal opportunity aimed at expanding access to higher education to underrepresented communities and diversifying our campuses and workplaces.

- As you may recall, in 2003 Michigan won an important Supreme Court case reaffirming the use of affirmative action in achieving diversity (and trumping the Hopwood case in Texas). Yet three years later our state passed a constitutional amendment (Proposition 2) that banned affirmative action and now is driving down our minority enrollments.

Markets

These economic, geopolitical, and demographic factors are stimulating powerful market forces that are likely to drive a massive restructuring of the higher education enterprise, similar to that experienced by other economic sectors such as banking, transportation, communications, and energy.

It also seems clear that the financial model that has dominated American higher education for the past several decades is beginning to fray.

- Traditionally, this has involved a partnership among states, the federal government, and private citizens (the marketplace).

- In the past the states have shouldered the lion's share of the costs of public higher education through subsidies, which keep tuition low for students; the federal government has taken on the role of providing need-based aid and loan subsidies.

- A recent Brookings Institution study concluded: "the traditional model of higher education finance in the U.S. with large state subsidies to public higher education and modest means-tested grants and loans from the federal government is becoming increasingly untenable." (It is worth noting that a co-author of this study, Steven Orzag, is now director of the U.S. Office of Management and Budget and controls the purse strings of our federal government.

- The tuition and fees charged for private universities (and an increasingly number of public universities) have hit the wall ($35,000 for tuition and $50,000).

- The tuitions at public universities are also rising rapidly. For example at both U California and U Michigan state residents pay $12,000 a year, and out-of-state students pay private tuition levels at $35,000 a year!

We are moving toward a revenue-driven, market-responsive higher education system because there is no way that our current tax system can support the degree of universal access to postsecondary education required by knowledge-driven economies in the face of other compelling social priorities (particularly the needs of the aging).

- This is amplified by an accelerating influence of the market on higher education and a growing willingness on the part of political leaders to use market forces as a means of restructuring higher education in order to increase the impact of the competition.

- Put another way, market forces are rapidly overwhelming public policy and public investment in determining the future course of higher education.

- Yet the increasing dominance of market forces over public policy raises two important challenges.

- Whether a deliberate or involuntary response to the tightening fiscal constraints and changing priorities for public funds, <u>the long standing recognition that higher education is a public good, benefiting all of our society, is eroding</u>.

Both the American public and its elected leaders increasingly view higher education as a private benefit that should be paid for by those who benefit most directly, namely the students. Without the constraints of public policy, earned and empowered by public investments, market forces could so dominate and reshape the higher education enterprise that many of the most important values and traditions of the university could fall by the wayside, including its public purpose.

Darwinian Competition

Furthermore, while the competition within the higher education marketplace can drive quality, if not always efficiency, there is an important downside.

Although many would question whether American higher education truly functions as a market, high student and faculty mobility among its thousands of institutions does create strong competition for the best faculty, the best students, resources from public and private sources, athletic supremacy, and reputation that can drive quality, albeit with considerable inefficiency and rising costs.

- However, it can also create an intensely Darwinian, winner-take-all ecosystem in which the strongest and wealthiest institutions can become predators, raiding the best faculty and students of the less generously supported and more constrained universities and

manipulating federal research and financial policies to sustain a system in which the rich get richer and the poor get devoured.

- This ruthless and frequently competition poses a particularly serious challenge to the nation's public research universities. These flagship institutions now find themselves caught between the rock of declining state support and the hard-place of the predatory rich private universities.

- As we have noted earlier, aging populations are not likely to give higher education a priority for state tax dollars for perhaps a generation or longer. Hence even as states are depending more on their public universities–expanding access to underserved communities, achieving world-class performance in research and graduate studies key to regional economic competitiveness–state appropriations are declining while demands for higher efficiency and accountability are intensifying.

- In sharp contrast, due both to booming financial markets and favorable federal financial aid and tax policies, many private universities have managed to build endowments so large (at least on a per student basis) that they have become independent of the education marketplace (e.g., student tuition, R&D grants, even private support).

This creates a serious competitive imbalance in the marketplace for the best faculty, students, and perhaps resources, since the wealth gap between the rich privates and flagship publics is growing ever larger.

- This is aggravated by the political constraints on public universities that not only limit their flexibility and agility, but also hinder their capacity to compete (e.g., constraints on tuition, affirmative action, technology transfer, and globalization).

The plight of the public research university is not only a serious challenge to the states but as well as to the nation, since these institutions represent the

backbone of advanced education and research, producing most of the scientists, engineers, doctors, lawyers, and other knowledge professionals, conducting most of the research, and performing most of the public service sought by states.

It would be a national disaster if the public research university were to deteriorate to the point in which research and advanced education of world-class quality could only occur in the 20 to 30 wealthiest private universities, as suggested by one of our leading private university presidents!

The Absence of a National Strategy

While most nations are facing–or at least coping with–the ongoing challenges of massification, academic competition, and limited public resources, local politics, culture, and history shape their particular approach.

The United States continues to rely on a highly decentralized market-driven approach, consistent with the constitutional role that the states play in higher education and the autonomy of private institutions, with little strategic direction from the federal government.

- In fact, the United States is essentially the only developed nation without a national strategy for higher education in general and for research universities in particular.

- Oh, we do have a competitive national research system, based on competitive grants from federal agencies such as NSF, NIH, DOE, and NASA.

- But the budgets and control of our public research universities– which do most of the research and produce most of the scientists, engineers, physicians, and other knowledge professionals–are at the state level, which prevents a concentration of resources to build excellence.

Here is one area where Europe–and, in fact, the rest of the world, has a very decided advantage over the United States. The Bologna Process and successors such as the European Research Area have been important elements of a strategy to sustain and enhance a constellation of world-class research universities, key both to the economic strength and integration of the European Community. True, the current financial crisis has created some cracks where nationalism may seep through for a bit, but it has been a model that many of us in the New World admire greatly!

Today, more than ever, the United States need to development a national strategy for sustaining (and perhaps expanding) a system of world-class research universities.

- Actually we have done this before, back in the 19th century with the land-grant acts when the revenues from the sale of federal lands were provided to the states to build the public universities capable of conducting both the basic and applied research to address key national priorities such as agriculture and industry. The federal government stepped in once again after WWII to create a partnership between the research universities and federal agencies through a peer-reviewed competitive grant system.

- Today many of us believe we need a new national strategy similar to the Land-Grant Acts of the 19th century to sustain and enhance the quality of the nation's flagship public research universities.

One idea would borrow from the approach currently being used to address the nation's banking crisis by partially "nationalizing" leading state universities by providing sustained federal funding as a match to their sustained funding.

- If one imagined that two such hybrid state-federal public universities would be supported in each state, this might amount to an annual federal investment of $20 to $25 billion–not large within the current $3.5 trillion federal budget or the trillions of dollars now being used to restart the economy.

Of course, many of the same forces that were driving rapid change in engineering research, including demographics, globalization, and rapidly evolving technologies, were also at play in reshaping the nature of engineering practice, with important implications for engineering education.

- The changing workforce and technology needs of a global knowledge economy are dramatically changing the nature of engineering practice, demanding far broader skills than simply the mastery of scientific and technological disciplines.

- The growing awareness of the importance of technological innovation to economic competitiveness and national security is demanding a new priority for application-driven basic engineering research.

- The nonlinear nature of the flow of knowledge between fundamental research and engineering application, the highly interdisciplinary nature of new technologies, and the impact of cyberinfrastructure demand new paradigms in engineering research and development.

- Moreover, challenges such as the off-shoring of engineering jobs, the decline of student interest in scientific and engineering careers, immigration restrictions, and inadequate social diversity in the domestic engineering workforce are also raising serious questions about the adequacy of our current national approach to engineering.

Of course there have been numerous related reports over the past several years:

Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future, National Academies (Augustine, 2005)
 The National Innovation Initiative, Council on Competitiveness (Council on Competitiveness, 2006)
 Engineering Research and America's Future: Meeting the Challenges of a Global Economy, National Academy of Engineering (Duderstadt, 2005)

T*he Engineer of 2020 (Parts I and II)*, National Academy of Engineering (Clough, 2004, 2005)
Educating Engineers: Theory, Practice, and Imagination, Carnegie Foundation for the Advancement of Teaching (S. Sheppard and W. Sullivan, 2007)
 *The Science and Engineering Workforce: Realizing America's Potentia*l, National Science Board (NSB, 2003)
Moving Forward to Improve Engineering Education, National Science Board (NSB, 2007)

The purpose of this study is to pull together the principal findings and recommendations of the various reports concerning the profession of engineering, the technology and innovation needs of the nation, and the role played by human and intellectual capital, into an analysis of the changing nature of engineering practice, research, and education.

A Century Ago

Note that such a general approach is quite similar in spirit to that conducted for the medical profession almost a century ago.

- At that time medicine was facing a tipping point when society's changing needs, coupled with a changing knowledge base of medical practice, would drive a very rapid transformation of the medical profession, along with medical education, licensure, and practice.

- During the 19th-century, medical education had evolved from a practice-based apprenticeship to dependence primarily upon didactic education (a year of lectures followed by a licensing exam), losing the rigor of training critical to competent health care. Many students had less than a high school education and none required a college degree.

The Carnegie Foundation for the Advancement of Teaching commissioned noted educator (but not physician) Abraham Flexner to survey 150 medical

schools over a yearlong period and draft a report concerning the changing nature of the profession and the implications for medical education.

- As Flexner observed, medical education was a farce as it was taught in most schools, "without laboratories, without trained and salaried men, without dispensaries, and without hospitals".

- Flexner held up Johns Hopkins University as the standard to which all medical schools should be held, involving a full-time faculty, allied to a teaching hospital and integrated into a university (although other medical schools including Michigan, Harvard, and Pennsylvania had actually pioneered the practice of requiring a college education for admission into programs based on laboratory science and clinical training in a teaching hospital environment).

The Flexner Report of 1910 transformed medical education and practice into the 20th century paradigm of scientific (laboratory-based) medicine and clinical training in teaching hospitals (Flexner, 1910).

- The key to the impact of the report was to promote educational reform as a public health obligation: "If the sick are to reap the full benefit of recent progress in medicine, a more uniformly arduous and expensive medical education is demanded."

- Key would be the requirement that all physicians should be well-educated, highly trained diagnosticians and problem solvers who understand the laboratory basis for scientific knowledge and have become skilled through extensive clinical experience.

- A medical degree would require a four-year post-undergraduate program based on inductive teaching in medicine and science–learning by doing–in a university setting that joined investigative science to practical training.

The Flexner Report ignited a reform movement that transformed medical education and practice over the next several decades. Roughly two-thirds of

medical colleges based on the didactic education of undergraduates were closed as the post-baccalaureate training paradigm proposed by Flexner was accepted as the requirement for medical practice.

Here it is interesting to note that during his study of medicine, Flexner raised very similar concerns about engineering education even at this early period.

- "The minimum basis upon which a good school of engineering accepts students is, once more, an actual high school education, and the movement toward elongating the technical course to five years confesses the urgent need of something more."

During the past century there have been numerous efforts to conduct an analysis of engineering very similar in spirit to the Flexner Report.

- As Schowalter observes, "Appearance every decade of a definitive report on the future of engineering education is as predictable as a sighting of the first crocuses in spring" (Schowalter, 2003).

- Yet throughout the past century, engineering education has remained remarkably stable–to be sure, adding more scientific content, but doing so within a four-year undergraduate program based primarily upon scientific problem solving and resisting most efforts to elevate it to the post-graduate practice-based programs characterizing other learned professions such as medicine and law.

Today's Engineering Concerns

<u>Practice</u>

A radically new system for creating wealth has emerged that depends upon the creation and application of new knowledge and hence upon educated people and their ideas. Some three billion people who were excluded by the pre-Internet economy have now walked out onto a level playing field, from China, India, Russia, and Eastern Europe, regions with rich educational heritages.

Today's global corporations manage their technology activities to take advantage of the most capable, creative, and cost-effective engineering talent, wherever they find it. The rapid evolution of high quality engineering services in developing economies with low labor costs raises a serious question about the viability of the U.S. engineer. This is a moving target as global sourcing moves up the value chain to product design, development, and innovation.

The challenges to U.S. Engineers

- Engineers must develop the capacity of working in global markets characterized by great cultural diversity.

- This requires a much faster pace of innovation, shorter product cycles, lower prices, and higher quality than ever before.

- Global innovation requires a shift from traditional problem solving and design skills to more innovative solutions imbedded in an array of social, environmental, cultural, and ethical issues.

- And they must achieve several times the value-added of engineers in other parts of the world to sustain their competitiveness relative to global sourcing.

Yet,

- In the U.S. the engineering profession still tends to be held in relatively low public esteem compared to other learned professions such as law and medicine.

- American industry utilizes engineers as consumable commodities, subject to layoffs or off shoring when their skills become obsolete or replaceable by cheaper engineering services from abroad. Industry managers are limited in increasing head count of U.S. engineers

relative to off shoring; many said they would not recommend engineering to their children.

- Students sense this, as evidenced by declining interest in engineering relative to business, law, and medicine.

Research

- Large and growing imbalance in federal R&D funding (e.g., NIH = $30 B, NSF = $6 B)

- Federal R&D has declined from 70% of national R&D in 1970s to less than 30% today.

- Increased emphasis on short-term R&D in industry and government-funded R&D

- Deterioration of engineering research infrastructure

- Declining interest of U.S. students in STEM careers

- Eroding ability of U.S. to attract STEM students, scientists, and engineers from abroad.

Education

Workforce Concerns

- Student interest in science and engineering careers is at a low ebb– and likely to go much lower as the implications of global sourcing become more apparent!

- Cumbersome immigration policies in the wake of 9-11 along with negative international reaction to U.S. foreign policy is threatening the pipeline of talented foreign science and engineering students.

- It is increasingly clear that a far bolder and more effective strategy is necessary if we are to tap the talents of all segments of our increasingly diverse society (particularly women and underrepresented minorities).

International Comparisons

- While absolute comparison production of U.S. engineers (85,000/y) with China (350,000/y) and India (170,000/y), of far more importance is the trend, e.g. with China on a five-year doubling pace.

- Similarly, PhD comparisons of U.S. (17,000/y) and China (8,000/y) is misleading; China is doubling every 5 years.

- Today the U.S. currently produces less than 4% of world's engineers and this is dropping fast.

- Clearly the U.S. cannot achieve engineering leadership through the number of engineering graduates. It must focus instead on quality and value-added through new educational paradigms for a rapidly changing, global, knowledge-driven economy.

Same Old…Same Old…

- Curriculum still stresses analytical skills to solve well-defined problems rather than engineering design, innovation, and systems integration.

- Continue to pretend that an undergraduate education is sufficient, despite fact that curriculum has become bloated and overloaded, pushing aside liberal education.

- Fail to take a more formal approach to lifelong learning like other professions (medicine, law).

- Need to broaden education to include topics such as innovation, entrepreneurial skills, globalization, knowledge integration.

- One recent critic of engineering education put it this way: "We are attempting to educate 21st C engineers using a 20th C curriculum in 19th C universities!"

In summary, our analysis has arrived at the following key conclusions:

1. In a global, knowledge-driven economy, technological innovation–the transformation of knowledge into products, processes, and services–is critical to competitiveness, long-term productivity growth, and the generation of wealth.

- Preeminence in technological innovation requires leadership in all aspects of engineering: engineering research to bridge scientific discovery and practical applications; engineering education to give engineers and technologists the skills to create and exploit knowledge and technological innovation; and the engineering profession and practice to translate knowledge into innovative, competitive products and services.

2. To compete with talented engineers in other nations with far greater numbers and with far lower wage structures, American engineers must be able to add significantly more value than their counterparts abroad through their greater intellectual span, their capacity to innovate, their entrepreneurial zeal, and their ability to address the grand challenges facing our world.

3. It is similarly essential to elevate the status of the engineering profession, providing it with the prestige and influence to play the role it must in an increasingly technology-driven world while creating sufficiently flexible and satisfying career paths to attract a diverse population of outstanding students. Of particular importance is greatly enhancing the role of engineers both in influencing policy and popular perceptions and as participants in leadership roles in government and business.

4. From this perspective the key to producing such world-class engineers is to take advantage of the fact that the comprehensive nature of American universities provide the opportunity for significantly broadening the educational experience of engineering students, provided that engineering schools, accreditation agencies such as ABET, the profession, and the marketplace are willing to embrace such an objective.

- Essentially all other learned professions have long ago moved in this direction (law, medicine, business, architecture), requiring a broad liberal arts baccalaureate education as a prerequisite for professional education at the graduate level.

The Roadmap

To achieve these, we furthermore offer the following proposals for action:

1.   Engineering professional and disciplinary societies, working with engineering leadership groups such as the National Academy of Engineering, ABET, the American Association of Engineering Societies, and the American Society for Engineering Education, should strive to create a guild-like culture in the engineering profession, similar to those characterizing other learned professions such as medicine and law that aim to shape rather than simply react to market pressures.

The initial goal should be to create (actually, re–create) a guild culture for engineering, where engineers identify more with their profession than their employers, taking pride in being members of a true profession whose services are highly valued by both clients and society.

The necessary transformation is suggested by a transition in language:

- * Engineers: from *employees* to *professionals*
- * Market: from *employers* to *clients*
- * Society: from *occupation* to *profession*

2.   The federal government, in close collaboration with industry and higher education, should launch a large number of Discovery Innovation Institutes at American universities with the mission of linking fundamental scientific discoveries with technological innovations to build the knowledge base essential for new products, processes, and services to meet the needs of society.

3.   Working closely with industry and professional societies, higher education should establish graduate professional schools of engineering that would offer practice-based degrees at the post-baccalaureate level as the entry degree into the engineering profession.

- Perhaps the most effective way to raise the value, prestige, and influence of the engineering profession is to create true post-baccalaureate professional schools similar to medicine and law, which are staffed with practice-experienced faculty and provide clinical practice experience.

- More specifically, the goal would be the transformation of engineering into a true learned profession, comparable in rigor, prestige, and influence to medicine and law, by shifting the professional education and training of engineers to post-baccalaureate professional schools offering two- or three-year, practice-focused degree programs (e.g., M. Eng. or D. Eng.).

- The faculty of these schools would have strong backgrounds in engineering practice with scholarly interests in the key elements of engineering, e.g., design, innovation, entrepreneurial activities, technology management, systems integration, and global networking, rather than research in engineering sciences.

- Students would be drawn from a broad array of possible undergraduate degrees with strong science and mathematics backgrounds, e.g., from the sciences or mathematics or perhaps a

broader engineering discipline similar to the pre-med programs preparing students for further study in medicine.

4.   Undergraduate engineering should be reconfigured as an academic discipline, similar to other liberal arts disciplines in the sciences, arts, and humanities, thereby providing students with more flexibility to benefit from the broader educational opportunities offered by the comprehensive American university with the goal of preparing them for a lifetime of further learning rather than professional practice.

- If the professional elements of an engineering education were shifted to a true post-graduate professional school, it might provide a very significant opportunity to address many of the challenges that various studies have concluded face engineering education today at the undergraduate level.

- In particular, removing the burdens of professional accreditation from undergraduate engineering degree programs would allow them to be reconfigured along the lines of other academic disciplines in the sciences, arts, and humanities, thereby providing students majoring (or concentrating) in engineering with more flexibility to benefit from the broader educational opportunities offered by the comprehensive university.

5.   The academic discipline of engineering (or, perhaps more broadly, technology) should be included in the liberal arts canon undergirding a 21st-century undergraduate education for all students.

- Bill Wulf warns that today we have a society profoundly dependent upon technology, profoundly dependent on engineers who produce that technology, and profoundly ignorant of technology.

- From this perspective, one could make a strong case that today engineering–or at least technology–should be added to the set of liberal arts disciplines, much as the natural sciences were added to the trivium and quadrivium a century ago.

- Here we are not referring to the foundation of science, mathematics, and engineering sciences for the engineering disciplines, but rather those unique tools that engineers master to develop and apply technology to serve society, e.g., structured problem solving, synthesis and design, innovation and entrepreneurship, technology development and management, risk-benefit analysis, and knowledge integration across horizontal and vertical intellectual spans.

We recognize that the resistance to such actions will be considerable.

- Some companies will continue to seek low-cost engineering talent, utilized as commodities similar to assembly-line workers, with narrow roles, capable of being laid off and replaced by offshored engineering services at the slight threat of financial pressure.

- Some educators will defend the status quo, as they tend to do in most academic fields.

- And unlike the professional guilds that captured control of the marketplace through licensing and regulations on practice in other fields such as medicine and law, the great diversity of engineering disciplines and roles will continue to generate a cacophony of conflicting objectives that inhibits change.

Yet the stakes are very high indeed. During the latter half of the 20th century, the economic leadership of the U.S. was largely due to its capacity to apply new knowledge to the development of new technologies.

- With just 5% of the world's population, the U.S. employed almost one-third of the world's scientists and engineers, accounted for 40% of its R&D spending, and published 35% of its scientific articles.

- Today storm clouds are gathering as inadequate investment in the necessary elements of innovation—education, research, infrastructure, and supportive public policies—threatens this nation's technological leadership.

If one extrapolates these trends, it becomes clear that our nation faces the very real prospect of losing its engineering competence in an era in which technological innovation is key to economic competitiveness, national security, and social well-being.

Bold and concerted action is necessary to sustain and enhance the profession of engineering in America—its practice, research, and education. It is the goal of our study both to sound the alarm and to suggest a roadmap to the future of American engineering.

Implications for the University of Georgia

In the 19th century, a changing world demanded that the classical curriculum, the *trivium* and *quadrivium* of Greek, Latin, rhetoric, and geometry used to "transform savages into gentlemen" was augmented with the knowledge necessary to serve a rapidly changing world: the natural and social sciences, modern languages, literature, etc.

Today one can make a strong case that in a world increasingly shaped by technology, it is imperative that universities added to the liberal arts canon some exposure to technology in general and engineering in particular. Moreover, just as tomorrow's graduates will be unable to claim to be educated citizens of our global, knowledge-driven society, so too a university will not be complete without a significant engineering program at all levels, baccalaureate, graduate, and professional. (Just as it would be incomplete without history, economics, or business.)

Of course, this was once the University of Georgia's mandate. In 1866, in response to the Morrill Land-Grant Act, Georgia created programs in agriculture and the mechanic arts, the term then used for engineering. However in the 1930s state financial constraints and politics eliminate this program in favor of those at Georgia Tech.

Yet today it is clear that:
- the rapid growth of high-tech business in Georgia demands a significant expansion of engineering programs
- and just as significantly, the University of Georgia must build these programs rapidly if it is to respond to the increasingly technology-dependent nature of our society.

But what about Georgia Tech? Here we have a very interesting recent datapoint: Harvard has decided it can no longer serve its students or society with a small "engineering and applied science" program and close relationships downriver with MIT. Instead it has now created a full-fledged School of Engineering in Harvard College and is building an entirely new campus across the river to house it.

Here I might also note that all of the 15 public university campuses in Michigan have engineering programs, most at both the BS and graduate level.

What flavor of engineering is most appropriate for Georgia? Your highly interdisciplinary and distributed model is an interesting approach, also characterizing institutions such as Dartmouth and Harvard. Yet several features are essential in my view

- It should be comprehensive in both degree levels (BS, MS, Phd) and disciplines (electrical, mechanical, civil, chemical, computer, industrial, etc.)
- It should be comparable in size (enrollments and budgets) to your other major professional schools (e.g., business, law, medicine). (It doesn't have to grow to the size of our program at Michigan with 7,600 students and 400 faculty, but at least a faculty size of 100 and student enrollment of 2,000 or so.
- And you should strive to make it world class in quality, fully competitive with your colleagues in Atlanta!

Let me conclude by mentioning several paradigm changes, just over the horizon, that may be true "game-changers"

Lifelong Learning

Today the shelf life of education provided early in one's life, whether K-12 or higher education, is shrinking rapidly in face of the explosion of knowledge in many fields.

- Today's students and tomorrow's graduates are likely to value access to lifelong learning opportunities more highly than job security, which will be elusive in any event.

- They understand that in the turbulent world of a knowledge economy, characterized by outsourcing and off-shoring to a global workforce, employees are only one paycheck away from the unemployment line unless they commit to continuous learning and re-skilling to adapt to every changing work requirements.

- Furthermore, longer life expectancies and lengthening working careers create additional needs to refresh one's knowledge and skills through.

And, just as students increasingly understand that in a knowledge economy there is no wiser personal investment than education, many nations now accept that the development of their human capital through education must become a higher priority than other social priorities, since this is the only sure path toward prosperity, security, and social well-being in a global knowledge economy.

- Of course, establishing as a national goal the universal access to lifelong learning would require not only a very considerable transformation and expansion of the existing postsecondary education enterprise, but it would also require entirely new paradigms for the conduct, organization, financing, leadership, and governance of higher education in America.

- For example, most of today's colleges and universities are primarily designed to serve the young–either as recent high school graduates or young adults early in their careers. Yet achieving the objective of universal access to lifelong learning would expand enormously the population of adult learners of all ages.

- Traditional university characteristics such as residential campuses designed primarily to socialize the young with resources such as residence halls, student unions, recreational facilities, and varsity athletics would have marginal value to adult learners with career and family priorities.

- Such universal lifelong learning could change dramatically the higher education marketplace, providing for-profit institutions already experienced in adult education with significant advantages.

- Furthermore it seems likely that the only way that such ubiquitous access can be provided to lifelong learning to adults with career and family responsibilities will be through technology-mediated distance learning.

Nevertheless it is time for the nation to step up to its responsibility as a democratic society to enable all of its citizens to take advantage of the educational, learning, and training opportunities they need and deserve, throughout their lives, thereby enabling both individuals and the nation itself to prosper in an ever more competitive global economy.

The Global University

The emergence of a global knowledge economy is driven not only by pervasive transportation, information, and communications technologies but also by a radically new system for creating wealth that depends upon the creation and application of new knowledge and hence upon advanced education, research, innovation, and entrepreneurial activities.

- Both mature and developing nations are making major investments in building the knowledge infrastructure–schools, universities, research institutes, high-tech industry, cyberinfrastructure, public policies and programs–necessary to achieve prosperity and security in the knowledge economy.

- In parallel with these trends, there is a strong sense that higher education is also in the early stages of globalization. Of course there has been a long tradition of higher education through the exchange of students, faculty, and ideas and the development of international partnerships among institutions.

Yet globalization implies a far deeper interconnectedness with the world—economically, politically, and culturally.

- It also requires thoughtful, interdependent, and globally identified citizens.

- Institutional and pedagogical innovations are needed to confront these challenges and insure that the canonical activities of universities–learning, scholarship, and engagement–remain rich, relevant, and accessible.

- This is important because all too often in their efforts to achieve international scope, universities from developed nations sometimes adopt a colonial approach, establishing relationships or even campuses abroad in an effort not only to provide international experiences for their students but to tap the intellectual talent of other nations.

While universities must be responsive to the imperatives of a global economy and attendant to their local responsibilities, they must also become responsible members of the global community, that is, becoming not only universities in the world but also of the world.

- We may even see the emergence of truly global universities that not only intend to compete in the global marketplace for students, faculty, and resources, but are also increasingly willing to define their public purpose in terms of global needs such as public health, environmental sustainability, and international development.

- Note here we are talking about the emergence of "universities of the world and in the world", universities that not only compete in the global marketplace but define their public purpose in terms of global needs, e.g., global health, global sustainability, wealth disparity and poverty.

Paradigm Shift 3: Cyberinfrastructure

The information and communications technologies enabling the global knowledge economy–so-called cyberinfrastructure, the current term used to describe hardware, software, people, organizations, and policies evolve exponentially, doubling in power every year or so and amounting to a staggering increase in capacity of 100 to 1,000 fold every decade.

- It is becoming increasingly clear that we are approaching an inflection point in the potential of these technologies to radically transform knowledge work.

- To quote Arden Bement, Director of the U.S. National Science Foundation, "We are entering a second revolution in information technology, one that may well usher in a new technological age that will dwarf, in sheer transformational scope and power, anything we have yet experienced in the current information age."

Many leaders, both inside and outside the academy, believe that these forces of change will so transform our educational institutions–schools, colleges, universities, learning networks–over the next generation as to be unrecognizable within our current understandings and perspectives.

- Here I have a personal interest since my career as a nuclear scientist essentially overlapped the evolution of the digital computer. During the 1980s while I was leading Michigan, we were approached by the federal government to join with IBM in extending a small regional computer network into one that would link scientists with the nation's supercomputers. We chose a standard communication protocol (TCP-IP) and found to our surprise that the network was growing at the rate of 10% a month. In fact, the federal government suggested that we broaden our mission to connect together as well other federal networks in what we called the "Internetwork".

- Well, we all know what happened. The browser appeared, the commercial world found out about it, and eventually it grew so large that we had to spin it off in 1993 as the Internet.

- In recent years I have chaired several studies by our National Academies to understand the impact of this technology on universities.

- Today I currently chair the Advisory Committee on Cyberinstrastructure for the National Science Foundation.

Hence from these multiple perspectives I would like to offer a few observations and provocative speculations about the longer term impact of this technology on the university.

- Ironically, while we generally think in terms of Terabit/sec networks and petaflop supercomputers, I believe the most profound changes may be driven not by the technology itself but rather the philosophy of openness and access it imposes on its users.

Paradigm Shift 4: Open Learning Resources

Of particular importance are efforts adopting the philosophy of open source software development to open up opportunities for learning and scholarship

to the world by putting previously restricted knowledge into the public domain and inviting others to join both in its use and development.

MIT led the way with its OpenCourseWare (OCW) initiative, placing the digital assets supporting almost 1,800 courses in the public domain on the Internet for the world to use.

- Today, over 400 universities have adopted the OCW paradigm to distribute their own learning assets to the world, with over 7,000 courses now available online.

- Furthermore, a number of universities and corporations have joined together to develop open-source middleware to support the instructional and scholarly activities of higher education, already used by hundreds of universities around the world (e.g., Moodle and Sakai).

- Others have explored new paradigms for open learning and engagement, extending the more traditional yet highly successful models provided by open universities.

There are increasing calls for opening up both data collection and scholarly publication by both individual institutions and university organizations, including the European University Association and the Association of American Universities, although commercial publishers are attempting to block this through government regulation and litigation.

To this should be added projects to digitize printed material such as the Google Book in which a number of leading libraries (26 at last count in 35 languages) around the world have joined together with Google to digitize a substantial portion of their holdings, making these available for full-text searches using Google's powerful internet search engines.

- For example, over 6 million volumes at the University of Michigan have been already been digitized, with our complete 8 million volume library now projected to be online by 2010.

- Google now has over 12 million books full-text searchable and has recently negotiated with publishers to provide full-text access to the vast volume of "orphan" works, no longer in print.

- A number of U.S. universities (25 thus far) have pooled their digital collections to create the HathiTrust, adding over 400,000 books a month to form the nucleus of what could become a 21st century analog to the "Library of Alexandria". ("Hathi" means "elephant" in Hindi…)

While there are still many copyright issues that need to be addressed, it is likely that these massive digitization efforts will be able to provide full text search access to a significant fraction of the world's written materials to scholars and students throughout the world within a decade. In fact there has recently been a negotiation to provide access to millions of "orphan" works through an agreement with publishers similar to the music industry.

There are still other examples of what is now called social computing or networking:

- We all know well the rapid propagation of mobile technology, with over 4 billion people today having cell-phone connectivity and 1.2 billion with broadband access.

- Today's youth are digital natives, members of the Net Generation, comfortable with using the new techologies for building social communities–instant messaging, blogs, wiki's, virtual worlds, FaceBook, MySpace, Wikipedia (which even their professors use).

- Rather than access the vast knowledge resources provided through the open education resources movement through passive media such as books, this generation access knowledge and build social communities through 3-D virtual reality environments such as Second Life, the World of Warcraft, and Croquet in which all of the

senses are faithfully replicated to enable human interaction at a distance.

Paradigm Shift 5: The Future of the University? (Or something else…)

Imagine what might be possible if all of these elements could be pulled together, i.e.,

- Internet-based access to all recorded (and then digitized) human knowledge augmented by powerful search engines,

- open source software, open learning resources, and open learning institutions (open universities),

- new collaboratively developed tools (Wikipedia II, Web 2.0); and

- ubiquitous information and communications technology (e.g., cheap laptop computers or, more likely, advanced cell phone technology).

In the near future it could be possible that anyone with even a modest Internet or cellular phone connection will have access to the recorded knowledge of our civilization along with ubiquitous learning opportunities.

Imagine still further the linking together of billions of people with limitless access to knowledge and learning tools enabled by a rapidly evolving scaffolding of cyberinfrastructure increasing in power one-hundred to one thousand-fold every decade.

- This will not only challenge existing social institutions–corporations, universities, nation states, that have depended upon the constraints of space, time, laws, and monopoly,

- But it will enable the spontaneous emergence of new social structures as yet unimagined–just think of the early denizens of the Internet such as Google, MySpace, Wikipedia, …and, unfortunately, Al Queda.

In fact, we may be on the threshold of the emergence of a new form of civilization, as billions of world citizens interact together, unconstrained by today's monopolies on knowledge or learning opportunities.

Perhaps this, then, is the most exciting vision for the future of knowledge and learning organizations such as the university, no longer constrained by space, time, monopoly, or archaic laws, but rather responsive to the needs of a global, knowledge society and unleashed by technology to empower and serve all of humankind.

- And all of this is likely to happen during the lives of today's students…and, in fact, during the lives of most of you in this gathering this evening.

- These possibilities must inform and shape the manner in which we view, support, and lead higher education. Now is not the time to back into the future!!!

Whence and Whither the Revolution

Today the university today looks very much like it has for decades–indeed, centuries in the case of distinguished European universities such as the University of Vienna.

- We are still organized into academic and professional disciplines; still basing its educational programs on the traditional undergraduate, graduate, and professional discipline curricula; still financed, managed, and led as it has been for many years.

But if one looks more closely at the core activities of students and faculty, the changes over the past decade have been profound indeed.

- The scholarly activities of the faculty have become heavily dependent upon digital technology–rather cyberinfrastructure–whether in the sciences, humanities, arts, or professions.

- Although faculties still seek face-to-face discussions with colleagues, these have become the booster shot for far more frequent interactions over Internet.

- Most faculty members rarely visit the library anymore, preferring to access far more powerful, accessible, and efficient digital resources.

- Many have ceased publishing in favor of the increasingly ubiquitous preprint route.

- And, as we have suggested earlier, both student life and learning is also changing rapidly, as students bring onto campus with them the skills of the net generation for applying this rapidly evolving technology to their own interests, forming social groups, role playing (gaming), accessing services, and learning–despite the insistence of their professors that they jump through the hoops of the traditional classroom paradigm.

In one sense it is amazing that the university has been able to adapt to these extraordinary transformations of its most fundamental activities, learning and scholarship, with its organization and structure largely intact.

- Here one might be inclined to observe that technological change tends to evolve much more rapidly than social change, suggesting that a social institution such as the university that has lasted a millennium is unlikely to change on the timescales of tech turns– although social institutions such as corporations have learned the hard way that failure to keep pace can lead to extinction.

- Yet, while social institutions may respond more slowly to technological change, when they do so, it is frequently with quite abrupt and unpredictable consequences, e.g., "punctuated equilibrium".

It could also be that the revolution in higher education is well underway, at least with the early adopters, and simply not sensed or recognized yet by the body of the institutions within which the changes are occurring.

- Universities are extraordinarily adaptable organizations, tolerating enormous redundancy and diversity.

- It could be that information technology revolution is more a tsunami that universities can float through rather a tidal wave that will swamp them.

Perhaps we should view the transformation of the university as an evolutionary rather than a revolutionary process.

- Evolutionary change usually occurs first at the edge of an organization (an ecology) rather than in the center where it is likely to be extinguished.

- In this sense the cyberinfrastructure now transforming scholarship or the communications technology enabling new forms of student

learning and faculty scholarship have not yet propagated into the core of the university.

- Of course, from this perspective, recent efforts such as the Google Book project take on far more significance, since the morphing of the university library from stacks to Starbucks strikes at the intellectual soul of the university.

It is certainly the case that futurists have a habit of overestimating the impact of new technologies in the near term and underestimating them over the longer term.

- There is a natural tendency to implicitly assume that the present will continue, just at an accelerated pace, and fail to anticipate the disruptive technologies and killer apps that turn predictions topsy-turvy.

- Yet we also know that far enough into the future, the exponential character of the evolution of Moore's Law technologies such as info-, bio-, and nano- technology makes almost any scenario possible.

Certainly the monastic character of the ivory tower is certainly lost forever.

- Although there are 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.

- So too, 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.

Even in the near term, we should again recall Christensen's *innovators's dilemma*, as these disruptive technologies, which initially appear rather primitive, are stimulating the appearance of entirely new paradigms for learning and research that could not only sweep aside the traditional campus-based, classroom-focused approaches to higher education but seriously challenge the conventional academic disciplines and curricula.

- For the longer term who can predict the impact of exponentiating technologies on social institutions such as universities, corporations, or governments, as they continue to multiply in power a thousand-, a million-, and a billion-fold?

To be sure, there will be continuing need and value for the broader social purpose of the university as a place

- where both the young and the experienced can acquire not only knowledge and skills, but the values and discipline of an educated mind, so essential to a democracy;

- an institution that defends and propagates our cultural and intellectual heritage, even while challenging our norms and beliefs;

- the source of the leaders of our governments, commerce, and professions; and

- where new knowledge is created through research and scholarship and applied through social engagement to serve society.

But, just as it has in earlier times, the university will have to transform itself once again to serve a radically changing world if it is to sustain these important values and roles.