Remarks to the NSF Strategic Planning Group

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EARLIER STRATEGIC PLANNING EFFORTS

This exercise brings back memories, since in 1993 when Arden and I served on the NSB, we commissioned a similar effort. This commission chaired by Bill Danforth and Bob Galvin, included many of your colleagues (e.g., Lew Branscomb, John Armstrong, Jackie Barton, Marye Anne Fox, Frank Rhodes, Donna Shalala, and many others).

The commission began with the mission statement for the NSF: "To promote the progress of science; to advance national health, prosperity, and welfare; to secure the national defense; and for other purposes." (National Science Foundation Act of 1950) Their goal was to help the NSB better understand the role of science and engineering in meeting national goals and a better linking of scientific results with those goals. The Commission urged that the role of the NSF should be further clarified within an overall national policy, the goal of which should be to maintain the premier position of US science and engineering and its capability to contribute more fully to America's priorities.

The beginning premise was that while NSF represented only about 4% of the federal R&D budget, it has had extraordinary impact on our nation's leadership in science and engineering–and hence upon our national security, economic prosperity, and social well-being. Key here was its unusually broad mandate to strengthen American science and engineering, a partnership of trust with America's scientists, engineers, and academic institutions, a reliance on investigator initiated proposes and selection of the best of these based on merit, strong education programs, and the flexibility to pursue new ideas–all characteristics they believed should be preserved.

The 1993 NSB Commission recommended that both the NSB and the NSF leadership work closely with the White House to generate a strong science policy into which the NSF mission fit. In particular, they stressed the need for NSF to be both responsive to national needs as voiced by society as well as the intellectual priorities initiated by scientists and engineers. More specifically, the Commission set out two important goals:

i) To support first-rate research at many points on the frontiers of knowledge, identified and defined by the best researchers, and
ii) To achieve a balanced allocation of resources in strategic research areas in response to scientific opportunities to meet national goals.

While strongly supporting the initiation of proposals by investigators determined by merit, the Commission also cautioned that many fields not covered by traditional disciplines offered challenges for new knowledge and opportunities for creative, investigative research worthy of strong support, and this might require exceptions from current NSF funding practices.

A more recent NSB effort, the 2020 Vision Statement of 2005, echoed many of these themes of the earlier Commission. This study began with the concerns that the US is slipping in research, technology innovation, and education–the three essential pillars of a vibrant economy. It acknowledged that the environment was changing rapidly

because of challenges such as energy supply, environmental quality, public health, and national security. The Vision 2020 study set as priorities:

i) Ensuring the nation maintained a position of eminence at the global frontier of fundamental and transformative research, emphasizing areas of greatest scientific opportunity and potential benefit.
ii) Sustaining a world-class S&E workforce and foster the scientific literacy of all our citizens.
iii) Building the nation's basic research capacity through critical investments in infrastructure, including advanced instrumentation, facilities, cyberinfrastructure, and cutting-edge experimental capabilities.

and suggested as near term goals that:

i) The NSF should develop a comprehensive strategic plan that emphasizes the areas of greatest scientific opportunity and potential benefit to the nation.
ii) Strengthen opportunities for supporting transformative research.
iii) Critically evaluate current education investments and develop strategies to increase impact on STEM education.
iv) Ensure that new and more diverse generations of faculty will have significant opportunities to obtain research funding.

Of course there have been other such planning efforts, both conducted by the NSB as well as by NSF senior staff. Most have tended to stress "motherhood, apple pie, and the flag" themes without specifics. They generally are organized along broad themes such as "ideas, people, and tools" (terms frequently used to frame the planning over the past decade). The planning environment continues to evolve, e.g., from the end of the Cold War transition (early 1990s) to the dot-com evolution (late 1990s) to terrorism and national security (early 2000s) to today's concern with energy, climate change, and global sustainability. But today we have another theme: the hope and optimism associated with the recommendations of the National Academies "Rising Above the Gathering Storm" report and the corresponding America COMPETES Act that has authorized a doubling of NSF funding.

To be sure, some degree of "same old, same old" is quite appropriate, since the themes set out in the Danforth-Galvin Commission ring as true and important today as they did two decades ago. But I believe there are new challenges, responsibilities, and opportunities that should be considered in today's planning effort. Of particular importance is NSF's capacity to demonstrate its relevance to addressing the urgent priorities facing the nation and EARNING the support authorized through the America COMPETES act is best demonstrated through new, bold, and innovative programs.

Let me suggest several possibilities you might wish to consider.

SOME KEY THEMES

Intellectual ("ideas")

NSF is frequently criticized for the disciplinary silos resulting from the strong domain-focus of the R&RA directorates. Of course, this structure is necessary to some degree since many important scientific communities depend upon it. But there also needs to be

a balance between domain-specific activities and those that span (or perhaps even ignore) the traditional disciplines.

In a similar sense, there needs to be a better diversity and balance among the nature of research programs. One of your staff members once distinguished among "pathfinders" (research that breaks paradigms in a Kuhnian sense), "trailblazers" (that explore new directions), "pioneers" (that build the roads and establish the firm foundations of new activities), and "settlers" (that populate the new disciplines). In current language, this would be the spectrum from "transformational" to "established" to perhaps "translational" research activities. Again, the key here is balance, since all are important and necessary to fulfill NSF's dual responsibilities both to the scientific community and to the nation that supports these efforts.

Two related points: Transformational research requires "essential singularities" or "outliers" (to quote a popular book), those whose work falls beyond the radar screen but who may be the key to major advances. Unfortunately, these are just the folks usually ignored by peer review. Special steps are necessary to include them in your portfolio. Second, it is also important to remember that NSF's mission spans BOTH science AND engineering. While a growing amount of research activity spans both endeavors, the intellectual purpose of each differs: science tries to understand what is; engineering tries to create what has never been to address a societal need. And, of course, this is just the balance between curiosity-driven and use-inspired investigations sought by earlier planning efforts.

Education ("people")

Of course, the biggest challenge is K-12. Several years ago when I served on COSEPUP, we organized several meetings bringing together leading educators and scientists to understand the total disconnect between the expanding base of scientific knowledge in areas of neuroscience/cognitive science and teaching practice in our schools. Try as we might, we were unable to get a handle on just how the National Academies could remedy this divide. But since the NSF is actually the only federal agency doing real research on learning (the Department of Education is largely an entitlement focused organization with little rigorous research capacity), the Foundation has both a great opportunity as well as a national obligation to play a leadership role in this area (perhaps leading an interdepartmental effort with the DoEd and NIH). The NSF science of learning centers are an important start, but much more is needed.

The challenge in undergraduate education is a way to stimulate more experimentation (along the lines of Olin College) within a framework that will facilitate the propagation of successful efforts. (Here the recent CISE-OCI-EHR report on cyber-enabled learning may be helpful.) I view the NSF's most important role as one of catalyzing institution-based and largely institution-funded efforts through providing credibility through highly visible grants. Many institutions are ready to explore truly transformative projects but they need a political umbrella to allow them to push aside campus resistance. The prestige provided by an NSF grant can help them do this.

At the graduate level, it is long past time for a "Flexner Report" on the PhD, which is rapidly diverging in both character and objective among the disciplines. While the humanities still consider the purpose of the PhD as preparing future faculty, the physical sciences and engineering view it as preparing researchers, while the biomedical community now views it as only the next educational stage on the way to the postdoc, which has become the true "terminal" educational stage.

Another important issue: the original purpose of graduate education was to recapture the *universitas magistorium et scholarium* theme of a learning community of masters and scholars. Yet today, in many disciplines this has become a feudal system in which graduate students are frequently used as indentured servants in large research grants. This is driven, I believe, by the dominance of research assistantships as the primary mechanism for graduate student support in science and engineering. Perhaps now, some 40 years after the Mansfield Amendment, it is time to return to fellowships and traineeships as the dominant form of graduate student support, thereby providing more flexibility to graduate students and re-establishing the learning relationship between "masters and scholars" rather than the feudal relationship between lord and serf.

One more concern: It is becoming increasingly clear that the states are rapidly losing not only the capacity but, indeed, the rationale for the support of graduate (and professional) education at world-class levels. Not only are these graduates highly mobile, but the knowledge they produce through their research is quickly available to the world through "open" innovation and knowledge resource paradigms. More specifically, many of the states are beginning to conclude that they cannot, will not, and probably should not continue to support advanced education (or institutions) at world-class levels. Without federal intervention many of us fear that the United States will lose the contributions of world-class public research universities, since the priorities of the states (with aging populations) are rapidly diverging from those of the nation (e.g., competing in a knowledge-driven global economy). More on this later.

Infrastructure ("tools")

It strikes me that many disciplines (e.g., biomedical, engineering, social sciences) are evolving toward the need for large multi-institution research centers, much as physics and astronomy have done over the past several decades. Few institutions can afford the acquisition and maintenance of massive experimental or computational facilities (think clouds).

It is no longer enough for the NSF to fund principle investigators and avoid insofar as possible funding the capabilities required by those researchers. Unfortunately, the unrelenting pressure to fund more and more PI-based research has increased the burdens on research universities. Unpopular as it may be with research faculty, the Foundation needs to engage the issue of its responsibility for the support of research infrastructure in a comprehensive and systematic fashion.

The difficulty of addressing this need is exacerbated by the peer review funding approach. In some instances the best approach for the research community would be to award a single, at most several grants that would be tightly coordinated to provide a cost-effective facility or national infrastructure. Funding a number of loosely coordinated projects at a number of universities through peer review and competition is not only costly but also likely not to meet the needs of some fields. (Here a good example is cyberinfrastructure.) The upshot is that the NSF needs a different approach to community infrastructure needs–strong program officers combined with coordinating organizations like NCAR, although not limited to particular disciplines. Further, the NSF advisory structure needs to be more oriented to these challenges and less dominated by research faculty members who sometimes have little concern with the health of the overall research enterprise.

Funding (and Politics, of course)

Let me finally add to the holy trinity of people, ideas, and tools the not-so-holy theme of politics (or at least funding). Both the 1993 and 2005 NSB studies stressed the importance of an NSF portfolio balanced among curiosity/investigator-driven investigations and use-inspired programs aimed at addressing urgent national priorities. This, of course, has been a dominant theme of NIH, riding this approach to a funding level now six times that of NSF.

It is critical that NSF be more clearly seen by the "body politic" as absolutely essential to national priorities such as innovation-driven economic competiveness, energy sustainability, climate change (and global sustainability), science education, and even public health. While some of this is packaging and marketing, it is also the case that NSF needs to do a better job of aligning its programs with national priorities, since this is what the public (and their elected representatives) thinks it is paying for…

In the near term, I believe a highly visible role of NSF in addressing key national priorities is very important to getting America COMPETES reauthorized and adequately funded, particularly in a post-stimulus world with a serious federal current account deficit! This legislation is the near-term key to fixing the serious underfunding of the Foundation and enabling it to meet its current challenges, honor its responsibilities, and exploit some very exciting opportunity.

To this end, let me provide a few examples of the type of projects you should consider:

SOME EXAMPLES OF HOW NSF MIGHT BETTER ADDRESS NATIONAL PRIORITIES

Example 1: Climate Change and Global Sustainability

NSF has an extraordinary opportunity to play a critical leadership role in addressing the unusually broad issues associated with global sustainability (e.g., climate change, water resources, biodiversity), a challenge given the highest priority by the new administration as well as by an increasing number of world leaders. NSF's unusually broad span of scientific disciplines across the physical, biological, and social sciences, accompanied by its programs in engineering and education, put it in a highly strategic position, provided it rapidly launches innovative, high visibility programs to demonstrate its capacity to assume a leadership role in this critical area.

Example 2: Use-inspired Research (Pasteur's Quadrant)

Here, Chuck Vest provided me with several interesting ideas. He noted that over the past decade the nation has lost over 17 million manufacturing jobs, with another 6.7 million jobs lost in the current recession. Yet, over this same period, the IT revolution (driven in part by NSF programs such as NSFnet and CISE) has created 22 million new jobs! It is time to do this again, for example, with a new generation of manufacturing and robotics technology (IT and AI-based). He also notes that the National Academies "New Biology" Commission has recently proposed an initiative to augment the biological sciences with the capabilities of the physical and sciences and engineering (particularly systems engineering) to address urgent social priorities such as food, energy, water, and health. Here again, the unusual intellectual span of the Foundation positions it well to play a leadership role in such an effort. Finally Chuck stressed the importance of the NSF's significant involvement in energy and global sustainability. He noted that while other agencies (such as DOE) may have the lead in some areas, NSF's unique capacity to draw on talent from a very broad range of disciplines makes it

imperative that they agree to support outstanding proposals in areas that are viewed as the territory of other agencies. (Here my own example from past experience would be nuclear engineering and thermonuclear fusion, since while DOE has some programs in these areas, they tend to be very mission-focused and usually do not support the more fundamental investigations typical of NSF grants).

Chuck also pointed to the National Academy of Engineering's list of Grand Challenges as other possible opportunities (i.e., make solar energy economical, manage the nitrogen cycle, advance healthcare informatics, prevent nuclear terror, advance personalized learning, provide energy from fusion, provide access to clear water, engineer better medicine, secure cyberspace, engineer the tools of scientific discovery, develop carbon sequestration methods, restore and improve urban infrastructure, reverse engineer the brain, enhance virtual reality). Of course, many of these will involve applied research and development, technological innovation, and prototyping and deployment best done by other agencies and sectors. But NSF is capable of providing much of the knowledge base that will enable these efforts.

Example 3: Translational Research

As some of you know, I have been working with the Brookings Institution for the past year to push for a dramatic increase in federal investment in energy R&D, recommending that it be increased by an order of magnitude, and augmenting existing efforts with new paradigms more appropriate for addressing the complex, highly interdisciplinary challenge of building a sustainable energy infrastructure for the nation.

Here we have adapted an idea resulting from an earlier NSF grant, "discovery-innovation institutes", and combined it with the partnership and engagement philosophy of the land-grant acts to develop a powerful mechanism for coupling scientific research with technological innovation, commercialization, and deployment that seems to have stimulated considerable interest.

(In fact, our argument is that the challenge of building a sustainable energy infrastructure is quite different from massive technology development projects such as going to the moon since it involves building an entirely new economic sector based on renewable energy technologies. In this sense, a better model is provided by the Land Grant Acts that established agricultural and engineering experiment stations to conduct research and co-operative extension services to link with the marketplace in building a modern agricultural and industrial economy. In a sense the "discovery-innovation institute" is simply a 21st C representation of the 19th C paradigms of the agricultural experiment station.)

DOE has responded with its "energy innovation hubs" program, including them as the translational research component along with ARPA-E for transformational research and the EFRCs for better engaging research teams in both universities and the national laboratories. Perhaps NSF should think about a similar coordinated research structure to address some of the key national priorities.

Example 4: The Health of the American Research Enterprise

It is clear that the American research enterprise continues to evolve rapidly. Industry has shifted from corporate R&D (Bell Labs is only a parking lot today) to out-sourcing R&D to global "open innovation" paradigms. The national laboratories have been drifting

since the end of the Cold War, but may find themselves re-engaged on the development of sustainable energy technologies.

Many people believe that today the American university is also entering an era of rapid transformational change. The strong partnership between NSF and the nation's research universities provide it with both a compelling responsibility and unusual opportunity to participate in this transformation process. Indeed, I believe that the NSF played the most important role in shaping the emergence of the research university in post-WWII America. It is time to consider carefully and strategically how its programs might beneficially influence this next era of university transformation. In this spirit, let me move on to suggest several near term challenges as well as some longer-term paradigm shifts that should be considered.

CURRENT CHALLENGES FACED BY AMERICAN RESEARCH UNIVERSITIES

American higher education appears to be having difficulty responding to changes demanded by the emerging knowledge services economy, globalization, rapidly evolving technologies; an increasingly diverse and aging population; and an evolving marketplace characterized by new needs (e.g., lifelong learning), new providers (e.g., for-profit, cyber, and global universities), and new paradigms (e.g., competency-based educational paradigms, distance learning, open educational resources).

Furthermore, while American research universities continue to provide the nation with global leadership in research, advanced education, and knowledge-intensive services such as health care, technology transfer, and innovation, this leadership is threatened by rising competition from abroad, by stagnant support of advanced education and research in key strategic areas such as science and engineering, and by the complacency and resistance to change of the academy.

More specifically, I would identify the key near term challenges faced by the American university as follows:

Problem 1: A Collapsing Financial Paradigm

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 are planning to reduce expenditures by 15% or greater, as are several other of America's wealthiest private universities, whose operations had become heavily dependent on the income from long-term endowment investments of limited liquidity. Harvard has recently 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 retrenchment is on top of two decades of eroding tax support of public universities as the states have struggled with the shifting priorities of aging populations.

Today, the tuition and fees charged for private universities are now beyond the capacity of most families (e.g., $35,000/year for tuition and $50,000/year including housing). The tuition levels at public universities are also rising rapidly. For example, at both the

Universities of California and U Michigan, state residents pay $12,000 a year while out-of-state students pay private tuition levels at $35,000 a year.

A recent Brookings Institution study has 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." (One of the authors of this report was Peter Orzag!)

Problem 2: The challenge of diversity

American colleges and universities have long played an important role in providing educational opportunities and social mobility for a diverse society. 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. 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. Current projections suggest that by mid-century the United States will no longer have any single majority ethnic group (e.g., it will no longer be Euro-centric.)

But while the increasing diversity of the American population with respect to culture, race, ethnicity, and nationality is one of our greatest strengths, it is also one of the nation's most serious challenges since the imperatives of increasing diversity are complicated by social and economic factors that must be addressed by our educational institutions. The mechanisms used to achieve diverse campuses such as affirmative action have been challenged in the courts and through voter referenda. (In fact, I have a bit of personal experience here, since I was a named defendant in the University of Michigan case that went before the U.S. Supreme Court in 2003. We won that battle, only to loose the war when Michigan voters passed a referendum in 2008 banning affirmative action!)

Problem 3: Darwinian Competition

Although some 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 damaging 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 well-endowed private universities. Aging populations are not likely to give higher education a priority for state tax dollars for perhaps a generation or longer, and it is already clear that the "buy-low" opportunities afforded by the post-recession

environment will allow selected private institutions to rapidly replenish their endowments.

The plight of America's public research universities 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!

This last possibility brings me to perhaps the most serious challenges of all to higher education in the United States:

Problem 4: The lack 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, culture, tradition, and local politics shape their particular approach. Because of our origin as a federation of independent colonies (and then states), 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.

Of course, our nation does have a well-organized 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 conduct most of the research and produce most of graduates of advanced degree programs, are at the state level, with only minimal influence by policies of the federal government. Here is one area where Europe–and 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.

Today, more than ever, the United States needs to develop a national strategy for sustaining (and perhaps expanding) a system of world-class research universities. Actually, we have done this before, a century ago, with the Land-Grant Acts that provided the revenues from the sale of federal lands to the states to build the public universities that have provided educational opportunities to the working class and conducted 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 that gave rise, of course, to the NSF! Today, many of us believe we need a new national strategy to sustain and enhance the quality of the nation's research universities.

NOTE: It is my belief that the leadership of the American research university is at considerable risk and this requires attention of the federal government. Congress apparently shares this concern since it has asked the National Academies to conduct a

study of this issue, similar to the RAGS effort. Since the NSF has a major responsibility for the health of this component of the American research enterprise, it would seem most appropriate if the Foundation were to participant in and support this effort.

LONGER TERM ISSUES: PARADIGM SHIFTS OVER THE HORIZON

Paradigm Shift 1: Lifelong Learning

Today, the shelf life of education provided early in one's life is shrinking rapidly in face of the explosion of knowledge in many fields. Furthermore, longer life expectancy and lengthening working careers create an ongoing need to refresh one's knowledge and skills through both formal and informal learning. Hence, an increasing number of nations are setting the ambitious goal of providing their citizens with ubiquitous, lifelong learning opportunities.

Of course, this will require not only a very considerable transformation and expansion of the existing post-secondary education enterprise but also entirely new paradigms for the conduct, organization, financing, leadership, and governance of higher education. Yet, if successful, it could also create true societies of learning, in which the sustained development of knowledge and human capital become the key paths to economic prosperity, national security, and social welfare.

Paradigm Shift 2: The Global University

There is a strong sense that higher education is in the early stages of globalization, through the efforts of an increasing number of established universities to compete in the global marketplace for students, faculty, and resources; the rapid growth in international partnerships among universities; and the appearance of for-profit organizations (e.g., Apollo, Laureate) that seek to expand through mergers and acquisition into global enterprises. In fact, some suggest that we may soon see the emergence of truly global universities that not only compete in the global market place for students, faculty, and resources but are increasingly willing to define their public purpose in terms of global needs and priorities such as environmental sustainability, public health, wealth disparities, and poverty. Such “universities in the world and of the world” might form through consortia of existing institutions (e.g., the U.K.’s Open University), new paradigms, or perhaps even existing institutions that evolve beyond the public agenda or influence of their region or nation-state to assume a truly global character.

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 (Europe calls this e-science)–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. Cyberinfrastructure is providing “functionally complete” research environments, on the net…or in the cloud.

To quote NSF Director Arden Bement, "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.

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 500 universities have adopted the OCW paradigm to distribute their own learning assets to the world, with over 9,000 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 (Rice's Connexions Project)

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. To this should be added projects to digitize massive amounts of printed material such as the Google Book project 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. 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…) 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 for search access by late 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. 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.

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 can 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…)

So what are the implications of these emerging technologies for the future of the university? John Seely Brown suggests that we might think of the contemporary university as an interconnected set of three core competencies: learning communities, knowledge resources, and the certification of knowledge skills. Social computing will empower and extend learning communities beyond the constraints of space and time. Open knowledge and education resources will clearly expand enormously the knowledge resources available to our institutions. And immersive environments will enable the mastery of not simply conventional academic knowledge but as well tacit knowledge, enabling our students to learn now only how "to know" and how "to do", but actually how "to be"–scholars, masters, professionals, whatever they wish! (Brown and Duguid, 2000)

But there is a possibility even beyond these. Imagine what might be possible if all of these elements are merged, 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 and access to network-based communities throughout the world (perhaps even through immersive environments such as Second Life). 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, which increases in power one-hundred to one thousand-fold every decade. This hive-like culture 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 Qaeda.

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.

SOME FINAL COMMENTS

I am confident that you folks have a similar list of highly innovative NSF programs capable of great impact on the nation. My point is that today the America COMPETES Act provides an extraordinary (perhaps once in a lifetime) opportunity to use such

programs as evidence of the importance of NSF to this nation.

Now is the time for bold action to make the case for the greatly enhanced sustained federal support necessary to achieve this potential. Every effort should be made to use at least a portion of this new funding for bold and innovative initiatives targeting major national priorities even if this pushes against some of the constraints placed on the funding and stimulates transformation both in research paradigms and institutions. You will have many allies in supporting these initiatives, while earning the public understanding and support necessary to achieve the goals of the America COMPETES Act.