Program For Academic Excellence Lecture Series
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Good evening, and thank you for inviting me to launch the Program for Academic Excellence Lecture Series. Almost half of my reason for being here is Nina McClelland's irresistible description of the importance of this series. The other more-than-half materialized when I performed my due diligence in response to her invitation. I found in the University of Toledo an institution whose mission and performance responds very well to a pattern of need that occurs throughout America today, and I am delighted to have an opportunity to congratulate UT on its successes and express thanks for the role it plays in the system of American enterprise.

This evening I want to talk about that system of enterprise – although I'm not sure "system" is the right word for the conditions in America that contribute to our economic strength. One of my colleagues on the President's Council of Advisors on Science and Technology calls it the "innovation ecology," a term that begins to express some of the complexity of a technology-based economy. Parts of the infrastructure for this ecology are the broad diversity of American higher education, and an appreciation for the value of science as a source of inspiration and of new technologies.

Earlier this year I was asked to speak at a Congressional event hosted by Michigan's physicist Congressman Vern Ehlers. He set the topic as *"Innovation and Technology for the 21st Century: Who will lead?"* And in the invitation he sent out for the event he quoted me as saying that "Technical innovation does not occur in a vacuum. It relies on an infrastructure of science, of skills, and of a nurturing environment for entrepreneurial fulfillment." I have learned that sometimes grand quotes like that appear by spontaneous generation, but in this case I actually did say it in a speech – and I believe it – and it is because such an infrastructure exists in our country that I am optimistic about the future of U.S. technical leadership. The University of Toledo is part of that infrastructure, and this evening I will repeat some of what I said at that earlier event on Capital Hill.

The question "Who will lead?" is somewhat provocative, suggesting doubt about outcomes, hinting of difficulties ahead, urging action to sustain our leadership. That is a healthy attitude because staying in first place requires constant self-assessment and questioning whether current ways are best. We collect a lot of data about ourselves, and agonize over every scrap that may reveal a weakness. In Washington we hear every day about international competition and what we ought to do about it. As a matter of fact, the U.S. does lead the world in science, technology, innovation, and economic productivity, and there is every prospect that we will continue to lead for a very long time.

Let me quote some more from the speech I mentioned. It was to the *World Summit on the Information Society* in Geneva last December, and it was one of those international meetings where each of 200 representatives speaks for about 3 minutes. I wanted to get across something of the flavor of the U.S. attitude toward innovation, in this case in the information technology sector: (The full speech is on the OSTP website.) Here's what I said:

> "Information and communication technology (ICT) is a key to the future prosperity of all nations.
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> "Prosperity in the United States owes much to this technology. Today the ICT industry comprises only eight percent of all enterprises in the American economy, but it produces twenty-nine percent of U.S. exports, generates high quality jobs, and contributes strongly to our productivity growth in all sectors. An estimated forty percent of U.S. productivity growth between 1995 and 2002 has been attributed to information technology. Our ability to seize the opportunities afforded by ICT depends upon a philosophy of shared optimism about the power of individual creativity and entrepreneurship as the ultimate source of economic strength.
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> "These human capabilities are universal. Every country has the potential to develop an information-based economy. ... [But] Technical innovation does not occur in a vacuum. It relies on an infrastructure of science, of skills, and of a nurturing environment for entrepreneurial fulfillment. My country is deeply committed to this algorithm of technology-based innovation. We endeavor to be a leader in its application. Our President, George W. Bush, has made continual development of the science and technology infrastructure for ICT a high priority. Our Government today invests more than two billion dollars annually in information technology research and development activities including aspects of large scale and broadband networking, advanced computing, software, and information management technologies."

Our commitment to the idea of science-based innovation is of course much stronger than indicated by these numbers just for ICT. Overall, the U.S. Government is committing more than one eighth of its domestic discretionary budget to research and development, about $130 billion, more than all other G-8 nations combined. I have heard complaints that half of that is for defense projects, and not basic research which provides the foundation for new technologies. That is true, but that half is an investment in scientific and engineering work, and it sustains a broad based technical workforce of high quality jobs. It produces intellectual property and skilled people who diffuse throughout the economy. The remaining $60 billion or more for non-military R&D still makes our scientists the envy of the world.

I know how envious our international partners are because I meet with them periodically to compare notes. Earlier this year I attended a conference of Science Ministers of the OECD nations in Paris. During that week the cover story of the European edition of *Time* Magazine was *"Europe's Brain Drain."* Where were the brains draining to? The United States. Why? Because, according to the interviews in the story, opportunities were better in the U.S. Better labs, better pay, greater independence, a chance to grow and follow their own genius rather than someone else's, and a chance to participate in a vibrant economy that values and rewards hard

work. Around the conference table, the representatives from nearly every nation expressed concern about their inability to keep their best and brightest at home. They talked about how to plug the drain. What were their plans? To emulate the United States.

Now it is not so easy to emulate the innovation system of the United States. In the first place, it is expensive. To quote the *Time* cover story, "In 2000, the U.S. spent 287 billion euros on research and development, 121 billion euros more than the E.U. No wonder the U.S. has 78% more high-tech patents per capita than Europe..." And today the U.S. figure is nearly 50% higher than in 2000. The *Time* article notes that "Only Finland and Sweden have reached the E.U. goal of spending 3% of GDP on research [most of Finland's research is by Nokia]. For the whole union to hit the target by 2010, R&D investment must grow by 8% a year – nearly twice the 4.5% annual increase recorded since 1997. It's not happening." In case you're interested, these R&D totals include private as well as public funds, and for the U.S., private sector research is twice the federal investment for a combined total of about 2.7% of GDP. Among countries with large GDP's, only Japan's percentage is greater than ours, at slightly more than 3%. In Japan, most R&D is funded by the private sector.

In the second place, regarding the difficulty of duplicating the U.S. innovation system, it is not just about money, and this is an essential point. Here's the *Time* article again: "No amount of funding can buy a culture of competitiveness. And if researchers don't see opportunities for reward, they'll take their talent to the States, where innovation and hard work are rewarded by generous grants, full credit and a financial stake in your work." Hear the words of some of the young scientists interviewed for the story: "The U.S. has an entrepreneurial culture." (from a Finn.) "Young people who prove they're good get many more opportunities, including perhaps the freedom to run their own labs" (from a Belgian.) "In Germany, the principle of reward for performance doesn't exist." (from a German.) "The U.S. is a place where you can do very good science, and if you're a scientist, you try to go to the best place." (from an Italian.) The *Time* article says "Some 400,000 European science and technology graduates now live in the U.S. and thousands more leave [Europe] each year. A survey released in November by the European Commission found that only 13% of European science professionals working abroad currently intend to return home."

Other countries are vigorously reorganizing their science agencies and policy shops to look like ours. Ireland, Japan, Russia, and South Korea, among others, have created Offices of Science and Technology Policy similar to our OSTP. Korea, Japan, Germany, Italy, France, and the U.K. are trying to cut loose their federally funded university systems to make them more entrepreneurial and capture their creativity to drive innovation, as we do with our research universities. They are considering Bayh-Dole-like arrangements to transfer ownership of intellectual property developed with federal funds to institutions motivated to develop them.

The role of universities in the U.S. innovation system is very difficult for other more centrally organized countries to appreciate. Higher education here is enormously diverse -- publics, privates, and proprietaries; large and small; specialized and universal; two-year and four-year. There is no federal regulation of higher education (other than that associated with the conduct of federally sponsored research, which I admit is not trivial). Financial aid is given mostly to the students, not to the institutions. Research funds (those not earmarked) are awarded

on the basis of merit, with special programs like EPSCOR for states that are still developing nationally competitive research programs. These are all market-oriented characteristics that encourage our institutions to continually improve themselves so as to compete for students, research support, and philanthropic gifts. The entire U.S. higher educational system is like a laboratory full of educational and organizational experiments. No one-size-fits-all reform can convert a federal university system in another country to look like ours.

In that Capital Hill event where I first gave these remarks, Congressman Ehlers asked what are the "critical challenges we must meet to maintain our leadership in innovation and technology in the face of new global realities and competition?" How about the Chinese? The Europeans worry about losing brains to the U.S., what do the Chinese worry about? There was a Chinese observer at the OECD meeting who said, "We are not worried about a brain drain. We have two million Chinese students studying abroad. If only one million come back, we are satisfied!" We all know that China is producing very large numbers of engineering and science graduates, outstripping the rest of the world. I think these production rates are too high, and will be self correcting as the graduates fail to find work. But the rates threaten to destabilize the global dynamics of the technical workforce. U.S. companies like – well, I won't name names here – are locating branches of their research centers in Beijing because of access to low-cost talent. China and India together have 40% of the world's population, and there is no question that their development will affect the balance of technology based innovation. We will have more equal international partners in the future because other countries are improving their ability to educate their people and modernize their economies. The challenge is for us to maintain our lead during this development. How do we do that?

I would say the first priority is to have confidence in our culture of entrepreneurship, of rewards based on merit, and of the talent each new generation brings into our society. Although it could always be tuned up, there is nothing very wrong with the structure of our system of higher education, or with the decentralized way we fund science, or with our reliance on universities rather than federal laboratories for doing basic research. Americans have traditionally worked hard and embraced technology, and it shows in our economic productivity data. The United States leads the world in Gross Domestic Product per employed person (except for tiny Luxembourg, which is always an outlier in these statistics.) The American culture and forms of government seem to me particularly well suited to compete successfully in a global technology-intensive economy.

Second, we need to cultivate the talent of each new generation by insisting on excellence at every step of educational progress, and to embrace the fundamental principle of "No Child Left Behind," so young people who aspire to be scientists and engineers have the skills they need to succeed at every step toward their careers. I have survived decades of discussion on how best to recruit young people to science and engineering, especially from among women and under-represented minority groups. Here I will only add an observation from my own experience teaching freshman physics in California and New York: Each year we had many incoming students who wanted to be scientists and engineers, but who dropped out after a semester or two of physics or chemistry. If we kept only half of those who dropped out, we could significantly increase the number of U.S. citizen engineering and science graduates. The main reason for the dropouts, in my direct experience, was lack of preparation for college level work – nearly always

in mathematics. I'm not talking about students who didn't have calculus, I'm talking about not being able to add fractions, not being able to interpret graphs, not being fluent enough in arithmetic to factor polynomials or simplify algebraic expressions. People would try to do algebra with calculators. These were students strongly motivated toward science and engineering, but not having the tools to succeed. This is what "No Child Behind" is all about. If we could lick the problem of preparation in lower grades, we would release a flood of talent that would reduce our current dependence on foreign students to provide the next generation technical workforce.

Third, we need to use our public funds wisely to support the activities that brilliant people from other countries find so attractive, and that produce the technologies and the innovations upon which our economic strength depends. That means continually adjusting our priorities so our investments in science can be sustained indefinitely.

There are some interesting facts about science funding in America that have profound implications for setting priorities. The part of the national budget that science money comes from is called the *domestic discretionary budget*. After accounting for inflation (*i.e.* in constant dollars deflated by the Consumer Price Index) the fraction of that budget devoted to non-military research and development has been practically constant at about 11% *for four decades* – with the single exception being the Apollo Project that sent men to the moon in the late 1960's and early 70's. The domestic discretionary budget itself has grown steadily during this time, so the amount available to science has been growing too, but not geometrically – in constant dollars the available pot of money has been growing approximately linearly with time.

These are very significant facts. If they apply to the future as well as to the past forty years, they imply that no area of science can grow at a steady percentage increase faster than the inflation rate without cutting into other areas of science. If we want to plus up a field, as we did with biomedical research between 1998 and 2003, then other fields have to tread water while we do it. Moreover, the fact that science costs inflate faster than the Consumer Price Index means that some fields have to decline as others increase in purchasing power. Some of the harsh consequences of these facts of life have been mitigated by increased industrial funding for research, and – in years when state treasuries are full – by increased state funding. In general, however, the competing demands of society do not permit all areas of science to grow at the rate they would wish. We have to prioritize and fund the areas with the greatest potential payoff for society and for new discoveries.

And finally, we must understand our complex innovation ecology well enough to ensure that its critical parts function smoothly – parts like research universities and their state and local government and industrial sponsors, or the legal structure for technology transfer and intellectual property protection, or tax incentives, or programs to encourage and assist small businesses.

Part of the innovation ecology is hidden machinery that includes things like synchrotron light sources, supercomputers, and other specialized equipment. It is not so easy to track investments in this machinery, or to ensure that it is properly funded. We fund research through a dozen agencies in a complex process whose fluctuations can knock out essential pieces if we are not careful. Keep in mind that ten of the thirteen appropriations committees in Congress

fund science, and in no one of these does science dominate. Offices like OSTP work with the departments and agencies, with Congress, and with other policy offices to focus the necessary attention on hidden but essential parts of the science and technology infrastructure. We need to raise the level of awareness of the roles each partner plays in the innovation infrastructure, and the science community needs to speak with a coherent voice about its needs and opportunities.

When it comes to science and technology based innovation, the future, at least for now, is moving in our direction. We will have been there first, and learned our lessons, and moved on with that wonderful restless, enterprising spirit that makes America such a great place to live and work.

The University of Toledo is part of a vast machinery that produces ideas, talent, and human energy that contributes to national leadership in science and technology. It is an important part because it provides focus for this region, and links students and faculty to regional needs, brings new life to the economy, and creates new opportunities for its people. Thank you for what you are doing for the future. And thank you for giving me an opportunity to talk about these things this evening.