The Knowledge Triangle: The American Challenge

Remarks Before
The Knowledge Triangle Shaping the Future of Europe Conference
Gothenburg, Sweden, September 2, 2009

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It is a pleasure to be here and offer my perspective on the knowledge triangle—the interaction between education, research, and innovation in the United States.

I have been involved in research and innovation-related issues for most of my career:

- First Assistant Secretary of Commerce for Technology Policy
- Assistant Director of International Affairs and Competitiveness at the White House Office of Science and Technology Policy
- As a program director at the National Science Foundation
- And, now, as President of the Council on Competitiveness

Over this career, I have seen a radical transformation of global science, technology, and innovation.

We are in an era of turbulence, transition, and transformation driven by:

- The digital revolution
- Globalization
- The entry of emerging economies into global business and markets, with 24-7 global labor arbitrage

- The increasing loss of routine manual and routine cognitive work to automation and lower-wage workers in emerging economies,
- And, the emergence of globally integrated enterprises

R&D capabilities around the world have risen rapidly. The number of innovator nations grows every year—driving a global dispersion of innovation.

New centers of research and innovation are springing up outside the traditional R&D centers. Countries as diverse as Brazil, Lithuania, and India are building their own innovation hubs and moving into high-value commercial activities. And emerging economies are increasing their share of foreign direct investment in high technology and R&D.

America has no lock on technological leadership. While, in 1960, the United States accounted for 69% of global R&D; today, <u>two-thirds of global R&D is performed somewhere other than the United States</u>.

These shifts have profound meaning for America:

- We can't keep or replicate the advantages of emerging economies
- We can't create more scientists and engineers than China or Indian
- We can't compete on low wages, commodity products, standard services, or routine technology development
- Educating and training our people to compete against a computer or low-wage workers in developing economies is a competition we cannot win, and

- Excellence in science and technology alone won't ensure our success, because many nations are building-up their own assets

Knowledge and technology are increasingly commodities in today's world, so rewards do not necessarily go to those who have a great deal of these things.

Instead rewards go to those who know what to do with knowledge, information, and technology once they get it. <u>It is innovation and ideas that matter most! And this has created an "innovation imperative" for the United States.</u>

America's success and our competitiveness in large measure will be built on our ability to exploit the unprecedented opportunities for innovation on the horizon. Let me mention just a few.

<u>We are on the cusp of profound technological development</u>. The digital, biotechnological, and nanotechnology revolutions are rewriting the rules of production and services in digital code, genetic code, and atomic code. These revolutionary technologies—each alone and in combination—will alter every industry. They are enablers for new business formation, platforms for new industries and new markets—<u>and they will unleash vast opportunities for innovation</u>.

<u>One of the most promising areas of opportunity is innovation that occurs at the intersection of disciplines and different spheres of activity</u>:

- Nano-biology
- Bioinformatics

- Agro-energy biotechnology
- Biomaterials which meld design, fabrication, and the life sciences
- Digital animation, which combines the skills of computer graphics specialists with skills of storytellers and actors

Biomimicry is a new driver for innovation, as biology and nature displace the machine as the model for design. For example:

- Strong, light weight steel sheets inspired by bird bones
- Competition swimsuits that replicate a shark's skin
- Vehicle anti-collision systems based on the way locusts swarm without running into each other

These multi-disciplinary fields are important areas for future investment in R&D and innovation.

In one last example of a target rich environment for innovation, there is a great and growing need to solve global grand challenges—food and water shortages, pandemics, security threats, the needs of aging populations worldwide, climate change, and the global need for cheap, clean energy.

These global challenges cry out for innovation—from low cost water purification and crops for harsh climates to low cost, portable health devices for the developing world.

The energy and environmental challenges have created a perfect storm for innovation. We can move to a new era of technological advances, market opportunity, industrial transformation, and innovation.

Energy and energy efficiency innovations are needed in transportation, appliances, green buildings, materials, fuels, power generation, industrial processes, and more. There are tremendous opportunities in renewable energy production—from utility-scale systems and small-distributed power, to bio-fuels and appropriate energy solutions for the developing world.

As Tom Friedman points out: "With three billion new consumers from India, Russia, and China joining the world economy, it is inevitable that manufacturing clean, green power systems, appliances, homes and cars will be the next great global industry."

The U.S. Knowledge Triangle

Faced with this "Innovation Imperative," the U.S. knowledge triangle becomes the core resource driving our economy.

Higher education sits at the nexus of research, education, and innovation. As many of you know, at the end of World War II, Vannevar Bush's report to President Truman—*Science the Endless Frontier*—recommended that the U.S. government take responsibility for promoting the flow of new scientific knowledge and developing scientific talent by funding basic research at universities.

This vision has underpinned America's science and technology effort ever since, and universities have become key building blocks in the U.S. innovation eco-system.

They are prolific generators of new knowledge and technology that have transformed our world, and helped raise standards of living across the globe.

They have produced a constant stream of world-class talent eager to push back the frontiers and give companies a competitive edge.

And they are the heart of numerous industry clusters humming in communities across America, driving new business formation and job creation.

By any measure, this is a story of success—a model of research enterprise emulated around the world. But it's not perfect…and dramatic changes in the global environment for science and technology challenge the status quo.

If America must become an "Innovation Economy"—a Creation Nation—then our universities are ever more important as wells of knowledge and technology from which the private sector must draw. But the interconnection between our universities and private sector innovation needs improvement.

First, in the United States, there is a disconnect between the training many scientists and engineers receive, and how they will ultimately work in the real world. Many research universities train scientists and engineers as if they were going to work in an academic research setting.

But, the vast majority of individuals whose highest degree is in science and engineering DO NOT work at a 4-year college or university—in fact, less than one in ten do. 59% work in the private sector. And the needs and work in the private sector are very different than in the academic research environment.

Entrepreneurial skills are valued in business broadly. And such skills are vital for science and technology professionals who start a high-tech business. We need to train for that.

Scientists and engineers who work in the business sector operate in fast-paced, highly goal-driven environments. They must understand the connection between their R&D projects and the business bottom-line. They must learn to communicate their ideas to non-technical people. And they need to embrace the fact that—in the private sector—science and technology are business issues first. We need to train for that.

As we see tremendous market opportunity outside the developed countries—by 2020, 80% of middle class consumers will live outside the developed world—researchers and product developers need a greater understanding of the different cultures they will serve. And as technical capability spreads worldwide, scientists and engineers need to be hunter-gatherers as well as creators of new knowledge and technology. We need to train them for this global perspective.

Second, for nearly three decades, we have encouraged academic researchers to consider commercial applications of their work, and to seek partnerships with the private sector.

In the 1980s, as Assistant Secretary of Commerce for Technology Policy, I was responsible for overseeing laws and policies—such as the Bayh-Dole Act of 1980 and the Federal Technology Transfer Act of 1986—that encourage the commercial application of government-funded research carried out at universities and Federal labs. While there has been some improvement in technology transfer, it has been an up-hill climb.

To more fully capture the economic benefits of public R&D investments, more American researchers need to better understand business and the marketplace, and the constraints under which businesses operate. These perspectives are important to the timely and smooth transfer of research and technology from academic and government labs to the private sector. But…

The way the U.S. research enterprise is structured frustrates this process. Challenges arise when the generators of new knowledge and technology are in universities, and users are in industry.

In an era of rapid change, this structural arrangement creates a cumbersome, <u>time-consuming technology transfer gap</u>, as new science and technology are <u>pushed</u> out of the academic sector, and then industry has to figure out what to do with it.

Also, R&D results and technology that emerge from academia are often too immature to attract financing for further development, and they languish. Of course, this is at the very heart of the valley of death problem.

The U.S. President's Council on Science and Technology—known as PCAST—assessed the U.S. National Nanotechnology Initiative, a $1.5 billion national research initiative. PCAST identified the limited dissemination of knowledge, skill, and expertise in nanotechnology as a continuing barrier to commercializing cutting edge ideas that come out of the lab.

PCAST said that the main way nanotechnology is transferred from universities to industry is when students are hired by companies or start new ones.[1] Why do we have to wait on a new hire or a start-up company to get new nanotechnology to industry? How, instead, do we create a broader and better ongoing flow of knowledge and know-how from universities to industry?

Third, there are significant cultural differences between universities and businesses that impede collaboration. For example, the time horizons at universities are simply incompatible with the fast pace of innovation in the private sector, and there are different approaches to intellectual property.

I think the allocation of U.S. research funds is emblematic of the cultural divide between industry and our research universities:

- About 6% of U.S. academic research is funded by industry, about $2.3 billion (in 2007).

[1] The National Nanotechnology Initiative: Second Assessment and Recommendations of the National Nanotechnology Advisory Panel, President's Council of Advisors on Science and Technology, April 2008.

- But, that $2.3 billion represents a mere 1% of industry's more than $220 billion in R&D spending (in 2007).[2]

This 1% should be considered in the context of three things:

1) Constraints limiting growth in U.S. government R&D investment, the traditional source of academic R&D funding;

2) The soaring level of U.S. industry R&D investment in recent years; and

3) The increasingly target rich R&D environment.

These conditions suggest the value of academia diversifying its sources of support for an expanded research effort.

I realize universities want research sponsors who do not place conditions on their research. But productive industry-university collaboration will require a process of accommodation.

If U.S. universities cannot bring themselves to some accommodation of industry, there are a growing number of universities around the world who would gladly do it.

[2] NSF data in constant dollars.

Finally, more disciplines—beyond the traditional science and engineering fields—must be prepared to contribute to innovation.

Twenty years ago the concept of innovation revolved largely around technology embedded in hardware, products, and processes.
But, the arrival of web-based businesses, novel approaches to service delivery, new media, and high-value lifestyle products and services are expanding our notions of what constitutes innovation.

In addition, many of today's grand global challenges—from food and water shortages, to energy and climate change—are complex and cut across the technical fields; not to mention the rapid advance and promise of the multi-disciplinary fields.

The academic and government research enterprise has been slow to respond to these important trends in innovation.

Traditional single-discipline, investigator-driven projects remain the dominant model of university research, and government funding to the academic community.

But no matter how excellent they may be, small single-discipline R&D projects lack the scale and scope for many of today's innovations…where, instead, we need different disciplines clustering around a challenge or goal, and integrating their diverse knowledge and skills.

Our innovation engine must be fueled by a cadre of professionals that goes beyond scientists and engineers—including designers, artists and entertainers, service and business model experts, market researchers, IT workers, social scientists, and others.

No one organization or discipline has all the necessary resources for high value innovation:

- **A skill base for driving high-value, game-changing innovation must span the arts, humanities, social sciences, business, design, marketing, finance, and management…as well as the sciences and engineering**
- **We need engineers that think like artists, and artists that think like engineers**
- **We need to bring the artist to scientific visualization, the materials scientist to fashion, and the cultural anthropologist to market research**

<u>**We need to deploy platforms, learning and working environments in which different disciplines can come together in a "cauldron of creativity" to fuel an explosion of ideas and innovations.**</u>

Professionals must come out of their disciplinary stovepipes

- Converge on problems and solutions
- Learn from each other
- And apply models from one field to another

American universities generally do not offer learning environments that cut across fields, or bring these other disciplines together with science and engineering.

There are other barriers that impede cross-disciplinary and multi-disciplinary work within the academic community, such as:

- Single-discipline organizational structures
- Reward systems
- Relatively small size of most grants
- Traditional peer review
- Publication practices
- Career paths within academia

I urge American universities to examine these traditional practices, and remove barriers that impede collaboration across the spectrum of academic disciplines.

U.S. government R&D funding does play a major role in how our academic research enterprise operates. And U.S. government funding has been slow to respond to more complex and multi-faceted science, technology, and innovation scenarios:

- For example, only about 5% of National Science Foundation investment in research goes for its research center programs, which are the principal means by which NSF fosters interdisciplinary research.

In closing, globalization and the <u>conceptualization of economic output</u> are now main features of the economic system at the dawn of the 21st century. They are challenging our historical advantages, affecting the structure of the U.S. economy, and who benefits most from American prosperity.

The fallout from this transition is a major tension cutting through our society and political narrative—reflected in our national discourse on individual economic security, free trade, outsourcing, the decline of manufacturing, jobs creation, income disparity, India, and China.

But the real question for our Nation's leaders is not how to shore-up for the last days of the Industrial Age, but rather how to shape the new Innovation Age that is rising rapidly to replace it.

A century ago, American society had to reorganize around the Industrial Age. Americans left farms, we built a huge industrial machine, we built roads and infrastructure to move an expanding range of mass-produced goods, our people learned new skills, and our government policies shifted to support this new kind of economy.

Much like the United States reorganized for the Industrial Age, we must now optimize our society for an Age of Innovation. We must put in place policies, investments, education, infrastructure, and other systems that will drive a “Creation Nation.” Because America will have to out-imagine, and out-create, **if we are to out compete.**

Thank you.

