S. HRG. 113–641

AMERICA COMPETES: SCIENCE AND THE U.S. ECONOMY

HEARING

BEFORE THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION UNITED STATES SENATE

ONE HUNDRED THIRTEENTH CONGRESS

FIRST SESSION

NOVEMBER 6, 2013

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SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

ONE HUNDRED THIRTEENTH CONGRESS

FIRST SESSION

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AMERICA COMPETES: SCIENCE AND THE U.S. ECONOMY

WEDNESDAY, NOVEMBER 6, 2013

U.S. SENATE,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, DC.

The Committee met, pursuant to notice, at 2:34 p.m. in room SR–253, Russell Senate Office Building, Hon. John D. Rockefeller IV, presiding.

OPENING STATEMENT OF HON. JOHN D. ROCKEFELLER IV, U.S. SENATOR FROM WEST VIRGINIA

The CHAIRMAN. Ladies and gentlemen, this hearing will come to order. And the vast attendance, let it fool you not, people will be coming in. That I'm on time is something of a miracle.

[Laughter.]

The CHAIRMAN. Much less other members.

I have no way of expressing how happy I am to welcome Senator Lamar Alexander.

I'm making, I just made the point to the Honorable Senator Thune that you and my son's wife's father were roommates at law school; is that correct?

Senator ALEXANDER. That's correct.

The CHAIRMAN. Was that Georgetown?

Senator ALEXANDER. NYU.

The CHAIRMAN. That's what I said.

And you, sir, have been a champion of this program from the very, very beginning. And I know that you have to leave right after your presentation, but we very much look forward to it. And so you're on.

Senator ALEXANDER. Well, thank you.

The CHAIRMAN. Give us history.

Senator ALEXANDER. I thought I'd have the privilege of listening to you and Senator Thune before, but I'll be glad to go ahead.

The CHAIRMAN. We'll go right after you.

Senator ALEXANDER. All right. Thanks very much.

The CHAIRMAN. Thank you.

STATEMENT OF HON. LAMAR ALEXANDER, U.S. SENATOR FROM TENNESSEE

Senator ALEXANDER. Thanks, Mr. Chairman, and Senator Ranking Member Thune, distinguished Senators. Thanks for letting me come by.

I'll try to keep my remarks to five minutes. I think that's what has been suggested to me. But let me start with exactly what I'm asking you to consider doing, and that is to authorize the appropriations committees to finish the job that the Congress started in an overwhelming remarkable bipartisan way in 2007 to double the research budgets of our—to double the budgets of our major research institutions in the Federal Government. That's what I am here to support.

And at the same time as you reauthorize America COMPETES, look for duplicate programs, look for waste; this is a time when we don't have any money to waste; and reauthorize the necessary programs that were authorized in 2007 and 2010. But the main goal is to finish the job stated in 2007 by legislation that was sponsored by the majority leader and by the minority leader and at one time, based on my memory, had 35 Republican sponsors and 35 Democratic sponsors. We'd never seen anything quite like it.

And then when the Senate changed hands and we went from a Republican to a Democratic Senate, the principle sponsors just switched positions and sponsors became Senator Reed and Senator McConnell. So that's the history of the American COMPETES legislation. Now.

Let me see if I can be persuasive here by posing a question. Why do you suppose that the United States is able to produce 22 percent of all the money in the world and distribute it among just below 5 percent of all the people in the world? How did we get that fortunate?

Well, there are many reasons, but basically our brains are the same as people around the world. We work hard, but we don't work that much harder than people in other countries. So how did this happen?

Most people believe that, while there are many factors, that the overwhelming factor since World War II is our technological advantage. In other words, we have a high standard of living because of our technological advantage since World War II.

It's because of stories like this, a small government agency called DARPA in the Defense Department, which was founded in 1958 at about the time of the Sputnik trouble and in which the U.S. Government invests small amounts of money in startup companies and then sends them out in the marketplace to see if they survive and often buys what they produce.

DARPA has invented such things as the Internet, stealth, speech-recognition software, and GPS, just a few things over that long period of time. Or a cousin to DARPA, which was created in 2007, by the legislation we're talking about today, which is called ARPA–E, it's in the energy department, already it has given a few million dollars, 4 million dollars, to a startup company that has doubled the energy density of rechargeable Lithium batteries. In other words, that could make, that could cut in half the cost of a battery or cause an electric car to go twice as far.

Or there's another invention, innovation going on in ARPA–E, in which Senator, the Chairman will be especially interested; it will use electricity and CO_2 to make liquid fuel. If that works, and it hasn't worked yet in a commercially viable way, but if you can actually combine electricity and CO_2 in some way to produce liquid fuel that could be sold, why then you could burn all the coal we have in the United States because we already have a way to deal with pollution from sulphur, nitrogen, and mercury. We don't have a very good way to capture carbon, but if this works, we would in a commercially viable way.

Then in the Office of Science, there has recently been an innovation that creates an artificial retinae and literally allows blind people to begin to see. It doesn't work for everybody. It's just beginning, but it's a remarkable beginning.

And perhaps the most extensive story is the role of the Federal Government in unconventional gas. Our prosperity today depends a lot on cheap natural gas. And of course much of that came from our big market, from entrepreneurs, from capital, from private landownership, all those things; but also from support from the Federal Government in a hydraulic fracturing demonstration project and inventing three-dimensional mapping.

So it's literally true what the scientists at Sandia Laboratory told me, that it's hard to think of a major development in the physical and biological sciences since World War II that didn't have some government-sponsored research behind it.

Now the rest of the world has noticed that we produce 22 percent of all the money in the world and just have a little less than 5 percent of the people. In 2006 while we were first starting America COMPETES, I was part of a Senators delegation to China. I was lucky to go because it was led by Senator Stevens, who flew the first cargo plane in 1944 into China and Senator Inouye, who is a congressional Medal of Honor winner, so they were well treated over there.

And President Hu and Vice President Wu spent a lot of time with us. And what was interesting to me was instead of talking about Iraq, Iran, North Korea, all those subjects; they wanted to talk about American competitiveness and Chinese competitiveness. And President Hu walked down the Great Hall of China not long after that and announced that they would spend 4 percent of their GDP for 15 years in order to try to catch up with the United States and with other countries in terms of standard of living. So they wanted to use, they wanted to create a brain-power advantage for their standard of living. The same brain-power advantage we already have.

Now that's not how we have to do it in the United States. President Obama can't just summon all of us to the Great Hall of America and tell us what to do. We can't even tell ourselves what to do. We have a messy democratic process we have to follow, but we did that. And in 2005, I remember sitting in a budget hearing, the end of a long day, I was getting very discouraged because it reminded me of my days as Governor when I would sit there and watch all the Medicaid costs go up and it was taking money away from higher education and I knew that if I wanted to a pro-growth state, I had to improve the schools and the research and the higher education system.

I've seen the same thing happen here in the Federal budget. All the money for entitlement is going up. We're squeezing out the investments in the research that has given us our high standard of living. So I walked down to the National Academy of Sciences that day, they were completing a meeting, and I said, "I believe if you all would tell us the ten things in priority order that we could do as a Congress that would make America more competitive, I believe we'd do it." Because what we usually lack around here is the lack of a specific idea.

They assembled a distinguished group of 20, Norman Augustine headed it, and very quickly they produced something, a report called, "Rising Above the Gathering Storm," which has gotten pretty famous. They recommended 20 things for us to do. We went to work through three committees including this one. It was very complicated. We had lots of Senators involved. We had many hearings. We got President Bush involved.

Long and short, after 2 years we were at a point where we almost unanimously passed a plan, whose major feature was to authorize the doubling of research in our scientific enterprises over the next 7 years. As I said, it was sponsored by the majority and minority leader and it had 70 or 80 members of the Senate as cosponsors of the bill and it had been through three different committees to get it done.

Well, we haven't quite lived up to what we said we would do, but we've done pretty well. About two-thirds of the recommendations from here are enacted into law. We are asking you to reauthorize those that work. And we've made some progress on funding the National Academy of—the National Science Foundation, the National Institute of Standards and Technology, the Office of Science in the Department of Energy, and the new little ARPA–E endeavor that I talked about, which is $264 million of funding this year.

So what there is to do in this committee, I would respectfully suggest, is to authorize the appropriations committees to finish the job of doubling our funding for research so we can keep our high standard of living.

Where does the money come from? These are tight times. Well, our budget is $3.6 trillion. Our research funding is 4 percent of that, so $140 billion, which seems like a lot; but the Chinese level of funding for the next 15 years is 4 percent of their gross domestic product. If we were to do 4 percent of our gross domestic product, we'd have a research budget of $600 billion, 4 times what it actually is.

And we ought to, you know, governing is about setting priorities, there are plenty of things we do that are less important than this, if we want to keep our high standard of living. Now I know there are some on my side of the aisle who sometimes think that the authorizing committees are supposed to also be the appropriations committees. I don't. You know, if that's the case, then we ought to get rid of one or the other.

So I think it's up to you, if I may say so, to authorize what our goals should be. And it's up to those of us on the appropriations committee to decide how much to spend each year.

So I thank you for your time. I wish you well in the progress. I would like to rekindle the same enthusiasm that we had when we began this in 2006 and 2007. And in case that enthusiasm is slow coming, I can read you this one sentence from the group of distinguished Americans who revisited our competitive position in the world last year and issued this question and this answer.

So where does America stand relative to its position of 5 years ago when the Gathering Storm report was prepared? Answer: The unanimous view of the Committee members participating in this preparation of this report is that our Nation's outlook has not improved, but rather has worsened. There are a lot of other people in the world who have good brains. There are a lot of other people in the world who work hard. They see we've got 22, 23 percent of all the money in the world each year for just 5 percent of the people, and they want a bigger share. So if we want to keep our standard of living, I suggest that we finish the job.

Thank you for your time.

[The prepared statement of Senator Alexander follows:]

PREPARED STATEMENT OF HON. LAMAR ALEXANDER, U.S. SENATOR FROM TENNESSEE

I want to thank the Chairman and Ranking Member for inviting me here today to speak on this important topic, America's competitiveness, and the law that helps to maintain America's competitiveness—The America COMPETES Act.

America COMPETES Act was signed into law under President Bush in 2007. This act authorized several important programs to maintain America's competitiveness.

To understand America COMPETES, it's important to recognize that this was a major bipartisan effort, so much so, that the America COMPETES legislation was introduced by the Senate Majority and Minority leaders and had *30 Republican Senators, 38 Democratic Senators and 1 Independent Senator* as cosponsors.

Few issues over the last decade have garnered this much bipartisan support; so let me explain why this does.

In 2005, a Republican Congress, in response to concerns from the National Academies and business and education leaders "that a weakening of science and technology in the United States would inevitably degrade its social and economic conditions and in particular erode the ability of its citizens to compete for high-quality jobs," sought to strengthen and ensure America's competitiveness.

We started this process by asking the National Academies what are the 10 things that Congress can do to ensure America's competitiveness?

The National Academies organized a committee of business, education, and science leaders led by former Lockheed Martin CEO Norman Augustine, which then responded to Congress with 4 recommendations and 20 action items in the "Rising Above the Gathering Storm" report.

We took this report, recommendations from the Council on Competitiveness, and President Bush's American Competitiveness Initiative and developed the America COMPETES Act, which was signed into law by President George W. Bush.

The results have been successful:

- A 2012 Government Accountability Office review of ARPA–E found that it "successfully funded projects that would *not* have been funded solely by private investors, in keeping with its goals"—These types of projects include better batteries for energy storage and addressing the growing global shortage of rare earth materials used in magnets that are used in electronics.
- Many of the Science, Technology, Engineering, and Mathematics (STEM) programs are contributing to their stated goals, such as integrating research with education, which has resulted in "more students deciding to go to graduate school or to consider a career in research."
- Lastly, America COMPETES funds research at our national labs, which are the crown jewel in the "innovation ecosystem." Just in the last decade there are several success stories from our national labs such as:
    - Tools for increased border security like millimeter wave scanners at airports
    - Energy efficiency technology that could save $5 billion in fuel costs for the long haul trucking industry
    - Advancing medicine like FDA-approved drugs for cancer and AIDS treatment and artificial retina technology—that allowed a blind man to detect motion and differentiate simple objects.

Even with these successes the work is not over, which is why we must reauthorize America COMPETES.

Just this month over *300 organizations,* including universities from *all 50 states* along with businesses like Intel, IBM, Proctor & Gamble & Nissan USA, and chambers of commerce from across the country, sent a letter urging Congress to close our "innovation deficit" by passing a strong America COMPETES Act reauthorization bill.

Updates and changes to the programs need to be made to continue to combat the ever-increasing global competition.

But these changes can be made while also encompassing the principles suggested in the aforementioned letter—a bill that "set[s] funding targets that call for *real and sustained growth* in funding for the National Science Foundation (NSF), National Institutes of Standards and Technology (NIST), Department of Energy Office of Science, and the Advanced Research Projects Agency-Energy (ARPA–E)."

Even in our current times of fiscal constraints, we must continue to fund research and development.

As Dr. Thom Mason, Director of Oak Ridge National Laboratory has said, "It's hard to think of a major technological breakthrough in the physical or biological sciences since World War II that has not been helped by government-sponsored research."

The CHAIRMAN. Powerful and eloquent.

Senator ALEXANDER. And may I submit for the record two things, Mr. Chairman? One is the abbreviated copy of this original report. It's just a few pages. And that, not this, but a few—a summary of it. And the second is a letter from, well, more than—or from 200 university presidents and many organizations across the country who support the importance of this reauthorization of America COMPETES.

The CHAIRMAN. Is Chuck Vest on that list? He should be.

Senator ALEXANDER. Well, Chuck Vest was a major——

The CHAIRMAN. He was head of MIT.

Senator ALEXANDER.—force——

The CHAIRMAN. Yes.

Senator ALEXANDER.—in terms of the early efforts along with Norm Augustine and a whole group of others. Chuck, he has been a very important part of all of this from the beginning.

The CHAIRMAN. As have you, sir.

[The information referred to follows:]

October 9, 2013

Hon. JOHN D. ROCKEFELLER IV, Chairman, Senate Committee on Commerce, Science, and Transportation, Washington, DC.	Hon. JOHN THUNE, Ranking Member Senate Committee on Commerce, Science, and Transportation, Washington, DC.

Dear Chairman Rockefeller and Ranking Member Thune:

As over 200 university presidents have stated in an *open letter* to President Obama and the U.S. Congress "[t]he combination of eroding Federal investments in research and higher education, additional cuts due to sequestration, and the enormous resources other nations are pouring into these areas is creating a new kind of deficit for the United States: *an innovation deficit."* We write now, as leading higher education, research, science and business organizations to urge you to send a clear signal that the U.S. Congress is serious about closing the innovation deficit by introducing and passing a strong America COMPETES Act reauthorization bill that authorizes increased funding for key U.S. science agencies.

In both 2007 and 2010, the U.S. Congress passed COMPETES legislation with bipartisan support. With the passage of these bills, Congress established funding targets aimed at doubling funding for these key Federal research agencies within seven years with the goal of ensuring continued U.S. leadership in science and technology which provides the foundation for our global and economic competitiveness. These bills sent an important message to the world that our Nation and Congress were resolute about addressing concerns raised about the future health of the United States economy by the 2007 National Academies Report "*Rising Above the Gathering*

Storm." This report came in response to a request from a bipartisan group of Senators and House Members who asked what actions policy makers needed to take *". . . to enhance the science and technology enterprise so that the United States can successfully compete, prosper, and be secure in the global community of the 21st century".*

Despite the difficulty of achieving the doubling goal for research funding in the current fiscal environment, we strongly believe a core component of a renewed America COMPETES Act—and one that will be essential for our support—must be to set funding targets that call for *real* and *sustained* growth in funding for the National Science Foundation (NSF), National Institutes of Standards and Technology (NIST), Department of Energy Office of Science, and the Advanced Research Projects Agency—Energy (ARPA–E).

We stand ready to work with you to make the case to the public and other Members of Congress that the Federal government must close the innovation deficit by making robust investments in science and education if we are to remain the world's innovation leader and continue to reap the economic and national security benefits of such investments.

Anything short of real and sustained growth in Federal science investments will take our country backward as other nations surge forward in their efforts to mimic America's success.

Sincerely,

The Following Endorsing Organizations (as of October 9, 2013):

Aerospace Industries Association
Alaska SeaLife Center
Albany Area Chamber of Commerce
American Association for the Advancement of Science
American Astronomical Society
American Chemical Society
American Educational Research Association
American Geophysical Union
American Geosciences Institute
American Institute of Biological Sciences
American Institute of Physics
American Mathematical Society
American Physical Society
American Physiological Society
American Political Science Association
American Psychological Association
American Society for Engineering Education
American Society for Microbiology
American Society of Agronomy
American Society of Civil Engineers
American Society of Plant Biologists
American Sociological Association
American Statistical Association
Annis Water Resources Institute, Grand Valley State University
Arizona State University
Arizona Technology Council
ASME
Association for Psychological Science
Association for the Sciences of Limnology and Oceanography
Association for Women Geoscientists
Association for Women in Science
Association of American Geographers
Association of American Universities
Association of Environmental & Engineering Geologists
Association of Independent Research Institutes
Association of Population Centers
Association of Public and Land-grant Universities
Association of Research Libraries
ASTRA, the Alliance for Science & Technology Research in America
Auburn University
Battelle
Bay Area Science and Innovation Consortium—BASIC
Bigelow Laboratory for Ocean Sciences
Binghamton University, the State University of New York
Boise State

Boston University
Brown University
Business-Higher Education Forum
California State University, Fullerton
Carnegie Mellon University
Case Western Reserve University
Center for Coastal Marine Sciences, California Polytechnic State University, San Luis Obispo
Center for Marine Science, University of North Carolina, Wilmington
Center for Policy on Emerging Technologies (C–PET)
Champaign County Economic Development Corporation
Chesapeake Biological Laboratory—University of Maryland Center for Environmental Science
CleanTECH San Diego
Clemson University
Coalition for National Science Funding
Cognitive Science Society
Columbia University
Columbus Chamber of Commerce
CompTIA
Computing Research Association
Consortium for Ocean Leadership
Consortium of Social Science Associations
Consortium of Universities for the Advancement of Hydrologic Sciences, Inc.
Council for Energy Research and Education Leaders
Council of Environmental Deans and Directors
Council of Graduate Schools
Council on Competitiveness
Council on Undergraduate Research
Cray, Inc.
Crop Science Society of America
Dauphin Island Sea Lab
Duke University
Ecological Society of America
Electrical Geodesics, Inc. (EGI)
The Electrochemical Society
Emory University
Energy Sciences Coalition
Federation of American Societies for Experimental Biology
Federation of Associations in Behavioral & Brain Sciences
Federation of Materials Societies
Florida Gulf Coast University Vester Marine Field Station
Florida Institute of Oceanography
Florida State University
Fox/Atkins Development LLC
Franz Theodore Stone Laboratory, The Ohio State University
Friday Harbor Laboratories, University of Washington
Fusion Power Associates
Geological Society of America
Georgia Institute of Technology
Georgia Research Alliance, Inc.
Georgia State University
Greater Bloomington Chamber of Commerce
Greater Boston Chamber of Commerce
Greater Durham Chamber of Commerce
Greater Merced Chamber of Commerce
Greater Pittsburgh Chamber of Commerce
Greater Providence Chamber of Commerce
Greater Raleigh Chamber of Commerce
Grice Marine Lab, College of Charleston
Harvard University
Hatfield Marine Science Center, Oregon State University
Hawaii Institute of Marine Biology, University of Hawaii
Hubbs-Sea World Research Institute
Human Factors and Ergonomics Society
Humboldt State University Marine Laboratory
IEEE–USA
Indiana University

Information Technology Industry Council
Institute of Marine and Coastal Sciences at Rutgers University
Institute of Marine Sciences, The University of North Carolina at Chapel Hill
Intel Corporation
International Business Machines Corporation (IBM)
International Society for Developmental Psychology
Iowa State University
Johns Hopkins University
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Moss Landing Marine Laboratories
Mote Marine Laboratory
Mount Desert Island Biological Laboratory
National Association of Colleges and Employers
National Association of Geoscience Teachers
National Association of Marine Laboratories
National Cave and Karst Research Institute
National Communication Association
National Council for Science and the Environment
National Ecological Observatory Network, Inc.
National Science Teachers Association
Natural Science Collections Alliance
New Mexico State University
NextEd
North American Commission on Stratigraphic Nomenclature (NACSN)
North Carolina State University
North Carolina State University, Center for Marine Sciences and Technology
North Dakota State University
Northeastern University
Northern Illinois University
The Ohio State University
The Optical Society
Orange County Business Council
ORAU (Oak Ridge Associated Universities)
Oregon Entrepreneurs Network
Oregon Nanoscience and Microtechnologies Institute (ONAMI)
Oregon State University
Pace University
Paleontological Society
PARC, a Xerox Company
The Pennsylvania State University
Population Association of America
Portland Business Alliance
Portland State University
Prince William Sound Science Center
Princeton University
Procter & Gamble Company
Psychonomic Society
Purdue University
QB3
Rensselaer Polytechnic Institute
Rice University
Rochester Institute of Technology
Rutgers, The State University of New Jersey

Rutgers University Marine Field Station
Sacramento Metropolitan Chamber of Commerce
San Francisco State University, Romberg Tiburon Center for Environmental Studies
Savannah State University
The Science Coalition
Seahorse Key Marine Laboratory, University of Florida
Seattle Metropolitan Chamber of Commerce
Seismological Society of America
Semiconductor Industry Association (SIA)
Semiconductor Research Corporation
Shoals Marine Laboratory
Silicon Valley Leadership Group
Skidaway Institute of Oceanography
Society for Industrial and Applied Mathematics
Society for Industrial and Organizational Psychology
Society for Neuroscience
Society for Personality and Social Psychology
Society of Economic Geologists
Society of Experimental Social Psychology
Society of Independent Professional Earth Scientists
Soil Science Society of America
South Dakota School of Mines & Technology
South Dakota State University
Southeastern Universities Research Association
Southern Arizona Leadership Council
SPIE, the international society for optics and photonics
Springfield Area Chamber of Commerce
SRI International
SSTI (State Science and Technology Institute)
Stanford University
The State University of New York
Stony Brook University
SupraSensor Technologies
Task Force on American Innovation
Technology Councils of North America (TECNA)
TechVoice
TechX
Texas A&M University
Texas Instruments
TRIDEC
Tucson Metro Chamber
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University of Wisconsin-Madison
University of Wisconsin-Milwaukee, School of Freshwater Sciences, Great Lakes WATER Institute
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Utah State University
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Women in Technology Tennessee
Woods Hole Oceanographic Institution
Wrigley Institute for Environmental Studies, University of Southern California
Yale University

cc: Members of the Senate Committee on Commerce, Science, and Transportation

Identical letters sent to:

Members of the House Committee on Science, Space and Technology
Members of the Senate Committee on Energy and Natural Resources
Members of the Senate Committee on Health, Education, Labor, and Pensions

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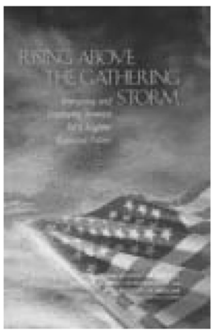

Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future

Committee on Prospering in the Global Economy of the 21st Century:An Agenda for American Science and Technology, National Academy of Sciences, National Academy of Engineering, Institute of Medicine

ISBN: 0-309-65442-4, 592 pages, 6 x 9, (2007)

Executive Summary

The United States takes deserved pride in the vitality of its economy, which forms the foundation of our high quality of life, our national security, and our hope that our children and grandchildren will inherit ever-greater opportunities. That vitality is derived in large part from the productivity of well-trained people and the steady stream of scientific and technical innovations they produce. Without high-quality, knowledge-intensive jobs and the innovative enterprises that lead to discovery and new technology, our economy will suffer and our people will face a lower standard of living. Economic studies conducted even before the information-technology revolution have shown that as much as 85% of measured growth in US income per capita was due to technological change.[1]

Today, Americans are feeling the gradual and subtle effects of globalization that challenge the economic and strategic leadership that the United States has enjoyed since World War II. A substantial portion of our workforce finds itself in direct competition for jobs with lower-wage workers around the globe, and leading-edge scientific and engineering work is being accomplished in many parts of the world. Thanks to globalization, driven by modern communications and other advances, workers in virtually every sector must now face competitors who live just a mouse-click away in Ireland, Finland, China,

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[1]For example, work by Robert Solow and Moses Abramovitz published in the middle 1950s demonstrated that as much as 85% of measured growth in US income per capita during the 1890-1950 period could not be explained by increases in the capital stock or other measurable inputs. The unexplained portion, referred to alternatively as the "residual" or "the measure of ignorance," has been widely attributed to the effects of technological change.

India, or dozens of other nations whose economies are growing. This has been aptly referred to as "the Death of Distance."

CHARGE TO THE COMMITTEE

The National Academies was asked by Senator Lamar Alexander and Senator Jeff Bingaman of the Committee on Energy and Natural Resources, with endorsement by Representative Sherwood Boehlert and Representative Bart Gordon of the House Committee on Science, to respond to the following questions:

> What are the top 10 actions, in priority order, that federal policymakers could take to enhance the science and technology enterprise so that the United States can successfully compete, prosper, and be secure in the global community of the 21st century? What strategy, with several concrete steps, could be used to implement each of those actions?

The National Academies created the Committee on Prospering in the Global Economy of the 21st Century to respond to this request. The charge constitutes a challenge both daunting and exhilarating: to recommend to the nation specific steps that can best strengthen the quality of life in America—our prosperity, our health, and our security. The committee has been cautious in its analysis of information. The available information is only partly adequate for the committee's needs. In addition, the time allotted to develop the report (10 weeks from the time of the committee's first gathering to report release) limited the ability of the committee to conduct an exhaustive analysis. Even if unlimited time were available, definitive analyses on many issues are not possible given the uncertainties involved.[2]

This report reflects the consensus views and judgment of the committee members. Although the committee consists of leaders in academe, industry, and government—including several current and former industry chief executive officers, university presidents, researchers (including three Nobel prize winners), and former presidential appointees—the array of topics and policies covered is so broad that it was not possible to assemble a committee of 20 members with direct expertise in each relevant area. Because of those limitations, the committee has relied heavily on the judgment of many experts in the study's focus groups, additional consultations via e-mail and telephone with other experts, and an unusually large panel of reviewers.

[2]Since the prepublication version of the report was released in October, certain changes have been made to correct editorial and factual errors, add relevant examples and indicators, and ensure consistency among sections of the report. Although modifications have been made to the text, the recommendations remain unchanged, except for a few corrections, which have been footnoted.

Although other solutions are undoubtedly possible, the committee believes that its recommendations, if implemented, will help the United States achieve prosperity in the 21st century.

FINDINGS

Having reviewed trends in the United States and abroad, the committee is deeply concerned that the scientific and technological building blocks critical to our economic leadership are eroding at a time when many other nations are gathering strength. We strongly believe that a worldwide strengthening will benefit the world's economy—particularly in the creation of jobs in countries that are far less well-off than the United States. But we are worried about the future prosperity of the United States. Although many people assume that the United States will always be a world leader in science and technology, this may not continue to be the case inasmuch as great minds and ideas exist throughout the world. We fear the abruptness with which a lead in science and technology can be lost—and the difficulty of recovering a lead once lost, if indeed it can be regained at all.

The committee found that multinational companies use such criteria[3] as the following in determining where to locate their facilities and the jobs that result:

- Cost of labor (professional and general workforce).
- Availability and cost of capital.
- Availability and quality of research and innovation talent.
- Availability of qualified workforce.
- Taxation environment.
- Indirect costs (litigation, employee benefits such as healthcare, pensions, vacations).
- Quality of research universities.
- Convenience of transportation and communication (including language).
- Fraction of national research and development supported by government.

[3]D. H. Dalton, M. G. Serapio, Jr., and P. G. Yoshida. *Globalizing Industrial Research and Development*. Washington, DC: US Department of Commerce, Technology Administration, Office of Technology Policy, 1999; Grant Gross. "CEOs Defend Moving Jobs Offshore at Tech Summit." *InfoWorld*, October 9, 2003; Bruce Mehlman. 2003. Offshore Outsourcing and the Future of American Competitiveness"; Bruce Einhorn et al. "High Tech in China: Is It a Threat to Silicon Valley?" *Business Week* online, October 28, 2002; B. Callan, S. Costigan, and K. Keller. *Exporting U.S. High Tech: Facts and Fiction About the Globalization of Industrial R&D*. New York: Council on Foreign Relations, 1997.

- Legal-judicial system (business integrity, property rights, contract sanctity, patent protection).
- Current and potential growth of domestic market.
- Attractiveness as place to live for employees.
- Effectiveness of national economic system.

Although the US economy is doing well today, current trends in each of those criteria indicate that the United States may not fare as well in the future without government intervention. This nation must prepare with great urgency to preserve its strategic and economic security. Because other nations have, and probably will continue to have, the competitive advantage of a low wage structure, the United States must compete by optimizing its knowledge-based resources, particularly in science and technology, and by sustaining the most fertile environment for new and revitalized industries and the well-paying jobs they bring. We have already seen that capital, factories, and laboratories readily move wherever they are thought to have the greatest promise of return to investors.

RECOMMENDATIONS

The committee reviewed hundreds of detailed suggestions—including various calls for novel and untested mechanisms—from other committees, from its focus groups, and from its own members. The challenge is immense, and the actions needed to respond are immense as well.

The committee identified two key challenges that are tightly coupled to scientific and engineering prowess: creating high-quality jobs for Americans, and responding to the nation's need for clean, affordable, and reliable energy. To address those challenges, the committee structured its ideas according to four basic recommendations that focus on the human, financial, and knowledge capital necessary for US prosperity.

The four recommendations focus on actions in K–12 education (*10,000 Teachers, 10 Million Minds*), research (*Sowing the Seeds*), higher education (*Best and Brightest*), and economic policy (*Incentives for Innovation*) that are set forth in the following sections. Also provided are a total of 20 implementation steps for reaching the goals set forth in the recommendations.

Some actions involve changes in the law. Others require financial support that would come from reallocation of existing funds or, if necessary, from new funds. Overall, the committee believes that the investments are modest relative to the magnitude of the return the nation can expect in the creation of new high-quality jobs and in responding to its energy needs.

The committee notes that the nation is unlikely to receive some sudden "wakeup" call; rather, the problem is one that is likely to evidence itself gradually over a surprisingly short period.

10,000 TEACHERS, 10 MILLION MINDS, AND K–12 SCIENCE AND MATHEMATICS EDUCATION

Recommendation A: ***Increase America's talent pool by vastly improving K–12 science and mathematics education.***

Implementation Actions

The highest priority should be assigned to the following actions and programs. All should be subjected to continuing evaluation and refinement as they are implemented.

Action A-1: Annually recruit 10,000 science and mathematics teachers by awarding 4-year scholarships and thereby educating 10 million minds. Attract 10,000 of America's brightest students to the teaching profession every year, each of whom can have an impact on 1,000 students over the course of their careers. The program would award competitive 4-year scholarships for students to obtain bachelor's degrees in the physical or life sciences, engineering, or mathematics with concurrent certification as K–12 science and mathematics teachers. The merit-based scholarships would provide up to $20,000 a year for 4 years for qualified educational expenses, including tuition and fees, and require a commitment to 5 years of service in public K–12 schools. A $10,000 annual bonus would go to participating teachers in underserved schools in inner cities and rural areas. To provide the highest-quality education for undergraduates who want to become teachers, it would be important to award matching grants, on a one-to-one basis, of $1 million a year for up to 5 years, to as many as 100 universities and colleges to encourage them to establish integrated 4-year undergraduate programs leading to bachelor's degrees in the physical and life sciences, mathematics, computer sciences, or engineering *with teacher certification*. The models for this action are the UTeach and California Teach program.

Action A-2: Strengthen the skills of 250,000 teachers through training and education programs at summer institutes, in master's programs, and in Advanced Placement (AP) and International Baccalaureate (IB) training programs. Use proven models to strengthen the skills (and compensation, which is based on education and skill level) of 250,000 *current* K–12 teachers.

- *Summer institutes:* Provide matching grants to state and regional 1- to 2-week summer institutes to upgrade the skills and state-of-the-art knowledge of as many as 50,000 practicing teachers each summer. The material covered would allow teachers to keep current with recent developments in science, mathematics, and technology and allow for the exchange of best teaching practices. The Merck Institute for Science Education is one model for this action.

• *Science and mathematics master's programs:* Provide grants to research universities to offer, over 5 years, 50,000 current middle school and high school science, mathematics, and technology teachers (with or without undergraduate science, mathematics, or engineering degrees) 2-year, part-time master's degree programs that focus on rigorous science and mathematics content and pedagogy. The model for this action is the University of Pennsylvania Science Teacher Institute.

• *AP, IB, and pre-AP or pre-IB training:* Train an additional 70,000 AP or IB and 80,000 pre-AP or pre-IB instructors to teach advanced courses in science and mathematics. Assuming satisfactory performance, teachers may receive incentive payments of $1,800 per year, as well as $100 for each student who passes an AP or IB exam in mathematics or science. There are two models for this program: the Advanced Placement Incentive Program and Laying the Foundation, a pre-AP program.

• *K–12 curriculum materials modeled on a world-class standard:* Foster high-quality teaching with world-class curricula, standards, and assessments of student learning. Convene a national panel to collect, evaluate, and develop rigorous K–12 materials that would be available free of charge as a *voluntary* national curriculum. The model for this action is the Project Lead the Way pre-engineering courseware.

Action A-3: Enlarge the pipeline of students who are prepared to enter college and graduate with a degree in science, engineering, or mathematics by increasing the number of students who pass AP and IB science and mathematics courses. Create opportunities and incentives for middle school and high school students to pursue advanced work in science and mathematics. By 2010, increase the number of students who take at least one AP or IB mathematics or science exam to 1.5 million, and set a goal of tripling the number who pass those tests to 700,000.[4] Student incentives for success would include 50% examination fee rebates and $100 mini-scholarships for each passing score on an AP or IB science or mathematics examination.

Although it is not included among the implementation actions, the committee also finds attractive the expansion of two approaches to improving K–12 science and mathematics education that are already in use:

• *Statewide specialty high schools:* Specialty secondary education can foster leaders in science, technology, and mathematics. Specialty schools immerse students in high-quality science, technology, and mathematics education; serve as a mechanism to test teaching materials; provide a training

[4]This sentence was incorrectly phrased in the original October 12, 2005, edition of the executive summary and has now been corrected.

ground for K–12 teachers; and provide the resources and staff for summer programs that introduce students to science and mathematics.

- *Inquiry-based learning:* Summer internships and research opportunities provide especially valuable laboratory experience for both middle-school and high-school students.

SOWING THE SEEDS THROUGH SCIENCE AND ENGINEERING RESEARCH

Recommendation B: ***Sustain and strengthen the nation's traditional commitment to long-term basic research that has the potential to be transformational to maintain the flow of new ideas that fuel the economy, provide security, and enhance the quality of life.***

Implementation Actions

Action B-1: Increase the federal investment in long-term basic research by 10% each year over the next 7 years through reallocation of existing funds[5] or, if necessary, through the investment of new funds. Special attention should go to the physical sciences, engineering, mathematics, and information sciences and to Department of Defense (DOD) basic-research funding. This special attention does not mean that there should be a disinvestment in such important fields as the life sciences or the social sciences. A balanced research portfolio in all fields of science and engineering research is critical to US prosperity. **Increasingly, the most significant new scientific and engineering advances are formed to cut across several disciplines.** This investment should be evaluated regularly to realign the research portfolio to satisfy emerging needs and promises—unsuccessful projects and venues of research should be replaced with research projects and venues that have greater potential.

Action B-2: Provide new research grants of $500,000 each annually, payable over 5 years, to 200 of the nation's most outstanding *early-career* researchers. The grants would be made through existing federal research agencies—the National Institutes of Health (NIH), the National Science Foundation (NSF), the Department of Energy (DOE), DOD, and the National Aeronautics and Space Administration (NASA)—to underwrite new research opportunities at universities and government laboratories.

Action B-3: Institute a National Coordination Office for Advanced Research Instrumentation and Facilities to manage a fund of $500 million in incremental funds per year over the next 5 years—through reallocation of existing funds or, if necessary, through the investment of new funds—to ensure that universities and government laboratories create and maintain

[5]The funds may come from anywhere in government, not just other research funds.

the facilities, instrumentation, and equipment needed for leading-edge scientific discovery and technological development. Universities and national laboratories would compete annually for these funds.

Action B-4: Allocate at least 8% of the budgets of federal research agencies to discretionary funding that would be managed by technical program managers in the agencies and be focused on catalyzing high-risk, high-payoff research of the type that often suffers in today's increasingly risk-averse environment.

Action B-5: Create in the Department of Energy an organization like the Defense Advanced Research Projects Agency (DARPA) called the Advanced Research Projects Agency-Energy (ARPA-E).[6] The director of ARPA-E would report to the under secretary for science and would be charged with sponsoring specific research and development programs to meet the nation's long-term energy challenges. The new agency would support creative "out-of-the-box" transformational generic energy research that industry by itself cannot or will not support and in which risk may be high but success would provide dramatic benefits for the nation. This would accelerate the process by which knowledge obtained through research is transformed to create jobs and address environmental, energy, and security issues. ARPA-E would be based on the historically successful DARPA model and would be designed as a lean and agile organization with a great deal of independence that can start and stop targeted programs on the basis of performance and do so in a timely manner. The agency would itself perform no research or transitional effort but would fund such work conducted by universities, startups, established firms, and others. Its staff would turn over approximately every 4 years. Although the agency would be focused on specific energy issues, it is expected that its work (like that of DARPA or NIH) will have important spinoff benefits, including aiding in the education of the next generation of researchers. Funding for ARPA-E would start at $300 million the first year and increase to $1 billion per year over 5-6 years, at which point the program's effectiveness would be evaluated and any appropriate actions taken.

Action B-6: Institute a Presidential Innovation Award to stimulate scientific and engineering advances in the national interest. Existing presidential awards recognize lifetime achievements or promising young scholars, but the proposed new awards would identify and recognize persons who develop unique scientific and engineering innovations in the national interest at the time they occur.

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[6] One committee member, Lee Raymond, does not support this action item. He does not believe that ARPA-E is necessary, because energy research is already well funded by the federal government, along with formidable funding by the private sector. Also, ARPA-E would, in his view, put the federal government into the business of picking "winning energy technologies"—a role best left to the private sector.

BEST AND BRIGHTEST IN SCIENCE AND ENGINEERING HIGHER EDUCATION

Recommendation C: ***Make the United States the most attractive setting in which to study and perform research so that we can develop, recruit, and retain the best and brightest students, scientists, and engineers from within the United States and throughout the world.***

Implementation Actions

Action C-1: Increase the number and proportion of US citizens who earn bachelor's degrees in the physical sciences, the life sciences, engineering, and mathematics by providing 25,000 new 4-year competitive undergraduate scholarships each year to US citizens attending US institutions. The Undergraduate Scholar Awards in Science, Technology, Engineering, and Mathematics (USA-STEM) would be distributed to states on the basis of the size of their congressional delegations and awarded on the basis of national examinations. An award would provide up to $20,000 annually for tuition and fees.

Action C-2: Increase the number of US citizens pursuing graduate study in "areas of national need" by funding 5,000 new graduate fellowships each year. NSF should administer the program and draw on the advice of other federal research agencies to define national needs. The focus on national needs is important both to ensure an adequate supply of doctoral scientists and engineers and to ensure that there are appropriate employment opportunities for students once they receive their degrees. Portable fellowships would provide a stipend of $30,000[7] annually directly to students, who would choose where to pursue graduate studies instead of being required to follow faculty research grants, and up to $20,000 annually for tuition and fees.

Action C-3: Provide a federal tax credit to encourage employers to make continuing education available (either internally or through colleges and universities) to practicing scientists and engineers. These incentives would promote career-long learning to keep the workforce productive in an environment of rapidly evolving scientific and engineering discoveries and technological advances and would allow for retraining to meet new demands of the job market.

Action C-4: Continue to improve visa processing for international students and scholars to provide less complex procedures and continue to make improvements on such issues as visa categories and duration, travel for

[7] An incorrect number was provided for the graduate student stipend in the original October 12, 2005, edition of the executive summary.

scientific meetings, the technology alert list, reciprocity agreements, and changes in status.

Action C-5: Provide a 1-year automatic visa extension to international students who receive doctorates or the equivalent in science, technology, engineering, mathematics, or other fields of national need at qualified US institutions to remain in the United States to seek employment. If these students are offered jobs by US-based employers and pass a security screening test, they should be provided automatic work permits and expedited residence status. If students are unable to obtain employment within 1 year, their visas would expire.

Action C-6: Institute a new skills-based, preferential immigration option. Doctoral-level education and science and engineering skills would substantially raise an applicant's chances and priority in obtaining US citizenship. In the interim, the number of H-1B visas should be increased by 10,000, and the additional visas should be available for industry to hire science and engineering applicants with doctorates from US universities.[8]

Action C-7: Reform the current system of "deemed exports." The new system should provide international students and researchers engaged in fundamental research in the United States with access to information and research equipment in US industrial, academic, and national laboratories comparable with the access provided to US citizens and permanent residents in a similar status. It would, of course, exclude information and facilities restricted under national-security regulations. In addition, the effect of deemed-exports[9] regulations on the education and fundamental research work of international students and scholars should be limited by removing from the deemed-exports technology list all technology items (information and equipment) that are available for purchase on the overseas open market from foreign or US companies or that have manuals that are available in the public domain, in libraries, over the Internet, or from manufacturers.

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[8]Since the report was released, the committee has learned that the Consolidated Appropriations Act of 2005, signed into law on December 8, 2004, exempts individuals that have received a master's or higher education degree from a US university from the statutory cap (up to 20,000). The bill also raised the H-1B fee and allocated funds to train American workers. The committee believes that this provision is sufficient to respond to its recommendation—even though the 10,000 additional visas recommended is specifically for science and engineering doctoral candidates from US universities, which is a narrower subgroup.

[9]The controls governed by the Export Administration Act and its implementing regulations extend to the transfer of technology. Technology includes "specific information necessary for the 'development,' 'production,' or 'use' of a product." Providing information that is subject to export controls—for example, about some kinds of computer hardware—to a foreign national within the United States may be "deemed" an export, and that transfer requires an export license. The primary responsibility for administering controls on deemed exports lies with the Department of Commerce, but other agencies have regulatory authority as well.

INCENTIVES FOR INNOVATION

Recommendation D: ***Ensure that the United States is the premier place in the world to innovate; invest in downstream activities such as manufacturing and marketing; and create high-paying jobs based on innovation by such actions as modernizing the patent system, realigning tax policies to encourage innovation, and ensuring affordable broadband access.***

Implementation Actions

Action D-1: Enhance intellectual-property protection for the 21st-century global economy to ensure that systems for protecting patents and other forms of intellectual property underlie the emerging knowledge economy but allow research to enhance innovation. The patent system requires reform of four specific kinds:

- Provide the US Patent and Trademark Office with sufficient resources to make intellectual-property protection more timely, predictable, and effective.
- Reconfigure the US patent system by switching to a "first-inventor-to-file" system and by instituting administrative review *after* a patent is granted. Those reforms would bring the US system into alignment with patent systems in Europe and Japan.
- Shield research uses of patented inventions from infringement liability. One recent court decision could jeopardize the long-assumed ability of academic researchers to use patented inventions for research.
- Change intellectual-property laws that act as barriers to innovation in specific industries, such as those related to data exclusivity (in pharmaceuticals) and those that increase the volume and unpredictability of litigation (especially in information-technology industries).

Action D-2: Enact a stronger research and development tax credit to encourage private investment in innovation. The current Research and Experimentation Tax Credit goes to companies that *increase* their research and development spending above a base amount calculated from their spending in prior years. Congress and the Administration should make the credit permanent,[10] and it should be increased from 20 to 40% of the qualifying increase so that the US tax credit is competitive with those of other countries. The credit should be extended to companies that have consistently spent large amounts on research and development so that they will

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[10]The current R&D tax credit expires in December 2005.

not be subject to the current de facto penalties for having previously invested in research and development.

Action D-3: Provide tax incentives for US-based innovation. Many policies and programs affect innovation and the nation's ability to profit from it. It was not possible for the committee to conduct an exhaustive examination, but alternatives to current economic policies should be examined and, if deemed beneficial to the United States, pursued. These alternatives could include changes in overall corporate tax rates and special tax provisions providing incentives for the purchase of high-technology research and manufacturing equipment, treatment of capital gains, and incentives for long-term investments in innovation. The Council of Economic Advisers and the Congressional Budget Office should conduct a comprehensive analysis to examine how the United States compares with other nations as a location for innovation and related activities with a view to ensuring that the United States is one of the most attractive places in the world for long-term innovation-related investment and the jobs resulting from that investment. From a tax standpoint, that is not now the case.

Action D-4: Ensure ubiquitous broadband Internet access. Several nations are well ahead of the United States in providing broadband access for home, school, and business. That capability can be expected to do as much to drive innovation, the economy, and job creation in the 21st century as did access to the telephone, interstate highways, and air travel in the 20th century. Congress and the administration should take action—mainly in the regulatory arena and in spectrum management—to ensure widespread affordable broadband access in the very near future.

CONCLUSION

The committee believes that its recommendations and the actions proposed to implement them merit serious consideration if we are to ensure that our nation continues to enjoy the jobs, security, and high standard of living that this and previous generations worked so hard to create. Although the committee was asked only to recommend actions that can be taken by the federal government, it is clear that related actions at the state and local levels are equally important for US prosperity, as are actions taken by each American family. The United States faces an enormous challenge because of the disparity it faces in labor costs. Science and technology provide the opportunity to overcome that disparity by creating scientists and engineers with the ability to create entire new industries—much as has been done in the past.

It is easy to be complacent about US competitiveness and preeminence in science and technology. We have led the world for decades, and we continue to do so in many research fields today. But the world is changing rapidly, and our advantages are no longer unique. Some will argue that this is a problem for market forces to resolve—but that is exactly the concern. Market forces are *already at work* moving jobs to countries with less costly, often better educated, highly motivated workforces and friendlier tax policies.

Without a renewed effort to bolster the foundations of our competitiveness, we can expect to lose our privileged position. For the first time in generations, the nation's children could face poorer prospects than their parents and grandparents did. We owe our current prosperity, security, and good health to the investments of past generations, and we are obliged to renew those commitments in education, research, and innovation policies to ensure that the American people continue to benefit from the remarkable opportunities provided by the rapid development of the global economy and its not inconsiderable underpinning in science and technology.

SOME COMPETITIVENESS INDICATORS

US Economy

- The United States is today a net importer of *high-technology* products. Its trade balance in high-technology manufactured goods shifted from *plus* $54 billion in 1990 to *negative* $50 billion in 2001.[1]
- In one recent period, low-wage employers, such as Wal-Mart (now the nation's largest employer) and McDonald's, created 44% of the new jobs while high-wage employers created only 29% of the new jobs.[2]
- The United States is one of the few countries in which industry plays a major role in providing healthcare for its employees and their families. Starbucks spends more on healthcare than on coffee. General Motors spends more on healthcare than on steel.[3]
- US scheduled airlines currently outsource portions of their aircraft maintenance to China and El Salvador.[4]
- IBM recently sold its personal computer business to an entity in China.[5]
- Ford and General Motors both have junk bond ratings.[6]
- It has been estimated that within a decade nearly 80% of the world's middle-income consumers would live in nations outside the currently industrialized world. China alone could have 595 million middle-income consumers and 82 million upper-middle-income consumers. The total population of the United States is currently 300 million[7] and it is projected to be 315 million in a decade.
- Some economists estimate that about half of US economic growth since World War II has been the result of technological innovation.[8]
- In 2005, American investors put more new money in foreign stock funds than in domestic stock portfolios.[9]

Comparative Economics

- Chemical companies closed 70 facilities in the United States in 2004 and tagged 40 more for shutdown. Of 120 chemical plants being built around the world with price tags of $1 billion or more, one is in the United States and 50 are in China. No new refineries have been built in the United States since 1976.[10]
- The United States is said to have 7 million illegal immigrants,[11] but under the law the number of visas set aside for "highly qualified foreign workers," many of whom contribute significantly to the nation's innovations, dropped to 65,000 a year from its 195,000 peak.[12]
- When asked in spring 2005 what is the most attractive place in the world in which to "lead a good life", respondents in only 1 (India) of the 16 countries polled indicated the United States.[13]

• A company can hire nine factory workers in Mexico for the cost of one in America. A company can hire eight young professional engineers in India for the cost of one in America.[14]

• The share of leading-edge semiconductor manufacturing capacity owned or partly owned by US companies today is half what it was as recently as 2001.[15]

• During 2004, China overtook the United States to become the leading exporter of information-technology products, according to the Organisation for Economic Co-operation and Development (OECD).[16]

• The United States ranks only 12th among OECD countries in the number of broadband connections per 100 inhabitants.[17]

K–12 Education

• Fewer than one-third of US 4th-grade and 8th-grade students performed at or above a level called "proficient" in mathematics; "proficiency" was considered the ability to exhibit competence with challenging subject matter. Alarmingly, about one-third of the 4th graders and one-fifth of the 8th graders lacked the competence to perform even basic mathematical computations.[18]

• In 1999, 68% of US 8th-grade students received instruction from a mathematics teacher who did not hold a degree or certification in mathematics.[19]

• In 2000, 93% of students in grades 5–9 were taught physical science by a teacher lacking a major or certification in the physical sciences (chemistry, geology, general science, or physics).[20]

• In 1995 (the most recent data available), US 12th graders performed below the international average for 21 countries on a test of general knowledge in mathematics and science.[21]

• US 15-year-olds ranked 24th out of 40 countries that participated in a 2003 administration of the Program for International Student Assessment (PISA) examination, which assessed students' ability to apply mathematical concepts to real-world problems.[22]

• According to a recent survey, 86% of US voters believe that the United States must increase the number of workers with a background in science and mathematics or America's ability to compete in the global economy will be diminished.[23]

• American youth spend more time watching television[24] than in school.[25]

• Because the United States does not have a set of national curricula, changing K–12 education is challenging, given that there are almost 15,000 school systems in the United States and the average district has only about six schools.[26]

Higher Education

• In South Korea, 38% of all undergraduates receive their degrees in natural science or engineering. In France, the figure is 47%, in China, 50%, and in Singapore, 67%. In the United States, the corresponding figure is 15%.[27]

• Some 34% of doctoral degrees in natural sciences (including the physical, biological, earth, ocean, and atmospheric sciences) and 56% of engineering PhDs in the United States are awarded to foreign-born students.[28]

• In the US science and technology workforce in 2000, 38% of PhDs were foreign-born.[29]

• Estimates of the number of engineers, computer scientists, and information-technology students who obtain 2-, 3-, or 4-year degrees vary. One estimate is that in 2004, China graduated about 350,000 engineers, computer scientists, and information technologists with 4-year degrees, while the United States graduated about 140,000. China also graduated about 290,000 with 3-year degrees in these same fields, while the US graduated about 85,000 with 2- or 3-year degrees.[30] Over the past 3 years alone, both China[31] and India[32] have doubled their production of 3- and 4-year degrees in these fields, while the United States[33] production of engineers is stagnant and the rate of production of computer scientists and information technologists doubled.

• About one-third of US students intending to major in engineering switch majors before graduating.[34]

• There were almost twice as many US physics bachelor's degrees awarded in 1956, the last graduating class before Sputnik, than in 2004.[35]

• More S&P 500 CEOs obtained their undergraduate degrees in engineering than in any other field.[36]

Research

• In 2001 (the most recent year for which data are available), US industry spent more on tort litigation than on research and development.[37]

• In 2005, only four American companies ranked among the top 10 corporate recipients of patents granted by the *United States* Patent and Trademark Office.[38]

• Beginning in 2007, the most capable high-energy particle accelerator on Earth will, for the first time, reside outside the United States.[39]

• Federal funding of research in the physical sciences, as a percentage of gross domestic product (GDP), was 45% less in fiscal year (FY) 2004 than in FY 1976.[40] The amount invested annually by the US federal government in research in the physical sciences, mathematics, and engineering combined equals the annual increase in US healthcare costs incurred every 20 days.[41]

PERSPECTIVES

• "If you can solve the education problem, you don't have to do anything else. If you don't solve it, nothing else is going to matter all that much." —Alan Greenspan, outgoing Federal Reserve Board chairman[42]

• "We go where the smart people are. Now our business operations are two-thirds in the U.S. and one-third overseas. But that ratio will flip over the next ten years." —Intel Corporation spokesman Howard High[43]

• "If we don't step up to the challenge of finding and supporting the best teachers, we'll undermine everything else we are trying to do to improve our schools." —Louis V. Gerstner, Jr., Former Chairman, IBM[44]

• "If you want good manufacturing jobs, one thing you could do is graduate more engineers. We had more sports exercise majors graduate than electrical engineering grads last year." —Jeffrey R. Immelt, Chairman and Chief Executive Office, General Electric[45]

• "If I take the revenue in January and look again in December of that year 90% of my December revenue comes from products which were not there in January." —Craig Barrett, Chairman of Intel Corporation[46]

• "When I compare our high schools to what I see when I'm traveling abroad, I am terrified for our workforce of tomorrow." —Bill Gates, Chairman and Chief Software Architect of Microsoft Corporation[47]

• "Where once nations measured their strength by the size of their armies and arsenals, in the world of the future knowledge will matter most." —President Bill Clinton[48]

• "Science and technology have never been more essential to the defense of the nation and the health of our economy." —President George W. Bush[49]

NOTES FOR *SOME COMPETITIVENESS INDICATORS AND PERSPECTIVES*

[1]For 2001, the dollar value of high-technology imports was $561 billion; the value of high-technology exports was $511 billion. See National Science Board. *Science and Engineering Indicators 2004*. NSB 04-01. Arlington, VA: National Science Foundation, 2004. Appendix Table 6-01. Page A6-5 provides the export numbers for 1990 and 2001 and page A6-6 has the import numbers.

[2]S. Roach. *More Jobs, Worse Work*. New York Times, July 22, 2004.

[3]C. Noon. "Starbuck's Schultz Bemoans Health Care Costs." *Forbes.com,* September 19, 2005. Available at: http://www.forbes.com/; R. Scherer. "Rising Benefits Burden." *Christian Science Monitor,* June 9, 2005. Available at: http://www.csmonitor.com/.

[4]S. K. Goo. *Airlines Outsource Upkeep*. Washington Post, August 21, 2005. Available at: http://www.washingtonpost.com/wp-dyn/content/article/2005/08/20/AR200508 2000979.html; S. K. Goo. *Two-Way Traffic in Airplane Repair*. Washington Post, June 1, 2004. Available at: http://www.washingtonpost.com/.

[5]M. Kanellos. "IBM Sells PC Group to Lenovo." *News.com,* December 8, 2004. Available at: http://news.com.com/IBM+sells+PC+group+to+Lenovo/2100-1042_3-5482284.html.

[6]See http://www.nytimes.com/.

[7]In China, P. A. Laudicina. *World Out of Balance: Navigating Global Risks to Seize Competitive Advantage*. New York: McGraw-Hill, 2005. P. 76. For the United States, see US Census Bureau. "US Population Clock." Available at: http://www.census.gov. For current population and for the projected population, see Population Projections Program, Population Division, US Census Bureau. "Population Projections of the United States by Age, Sex, Race, Hispanic Origin, and Nativity: 1999 to 2100." Washington, DC, January 13, 2000. Available at: http://www.census.gov/population/www/projections/natsum-T3.html.

[8]M. J. Boskin and L. J. Lau. Capital, Technology, and Economic Growth. In N. Rosenberg, R. Landau, and D. C. Mowery, eds. *Technology and the Wealth of Nations*. Stanford, CA: Stanford University Press, 1992.

[9]P. J. Lim. *Looking Ahead Means Looking Abroad*. New York Times, January 8, 2006.

[10]M. Arndt. "No Longer the Lab of the World: U.S. Chemical Plants are Closing in Droves as Production Heads Abroad." *BusinessWeek,* May 2, 2005. Available at: http://www.businessweek.com/ and http://www.usnews.com/usnews/.

[11]As of 2000, the unauthorized resident population in the United States was 7 million. See US Citizenship and Immigration Services. "Executive Summary: Estimates of the Unauthorized Immigrant Population Residing in the United States: 1990 to 2000." January 31, 2003. Available at: http://uscis.gov/graphics/shared/statistics/publications/2000ExecSumm.pdf.

[12]Section 214(g) of the Immigration and Nationality Act sets an annual limit on the number of aliens that can receive H-1B status in a fiscal year. For FY 2000 the limit was set at 115,000. The American Competitiveness in the Twenty-First Century Act increased the annual limit to 195,000 for 2001, 2002, and 2003. After that date the cap reverts back to 65,000. H-1B visas allow employers to have access to highly educated foreign professionals who have experience in specialized fields and who have at least a bachelor's degree or the equivalent. The cap does not apply to educational institutions. In November 2004, Congress created an exemption for 20,000 foreign nationals earning advanced degrees from US universities. See Immigration and Nationality Act, Section 101(a)(15)(h)(1)(b). See US Citizenship and Immigration Services. "USCIS Announces Update Regarding New H-1B Exemptions." July 12, 2005. Available at: http://uscis.gov/ and US Citizenship and Immigration Services. "Questions and Answers: Changes to the H-1B Program." November 21, 2000. Available at: http://uscis.gov.

[13]Pew Research Center. "U.S. Image Up Slightly, But Still Negative, American Character Gets Mixed Reviews." Washington, DC: Pew Global Attitudes Project, 2005. Available at: http://pewglobal.org/reports/display.php?ReportID=247.

The interview asked nearly 17,000 people the question: "Suppose a young person who wanted to leave this country asked you to recommend where to go to lead a good life—what country would you recommend?" Except for respondents in India, Poland, and Canada, no more than one-tenth of the people in the other nations said they would recommend the United States. Canada and Australia won the popularity contest.

[14]US Bureau of Labor Statistics. "International Comparisons of Hourly Compensation Costs for Production Workers in Manufacturing, 2004." November 18, 2005. Available at: ftp://ftp.bls.gov/.

[15]Semiconductor Industry Association. "Choosing to Compete." December 12, 2005. Available at: http://www.sia-online.org/.

[16]Organisation for Economic Co-operation and Development. "China Overtakes U.S. as World's Leading Exporter of Information Technology Goods." December 12, 2005. Available at: http://www.oecd.org/. The main categories included in OECD's definition of ICT (information and communications technology) goods are electronic components, computers and related equipment, audio and video equipment, and telecommunication equipment.

[17]Organisation for Economic Co-operation and Development. "OECD Broadband Statistics, June 2005." October 20, 2005. Available at: http://www.oecd.org/.

[18]National Center for Education Statistics. 2006. "The Nation's Report Card: Mathematics 2005." Available at: http://nces.ed.gov/nationsreportcard/pdf/main2005/2006453.pdf.

[19]National Science Board. *Science and Engineering Indicators 2004*. NSB 04-01. Arlington, VA: National Science Foundation, 2004. Chapter 1.

[20]National Center for Education Statistics. Schools and Staffing Survey, 2004. "Qualifications of the Public School Teacher Workforce: Prevalence of Out-of-Field Teaching 1987-88 to 1999-2000 (Revised)." 2004. P. 10. Available at: http://nces.ed.gov/pubs2002/2002603.pdf.

[21]National Center for Education Statistics. "Highlights from TIMSS." 2004. Available at: http://nces.ed.gov/pubs99/1999081.pdf.

[22]National Center for Education Statistics. "International Outcomes of Learning in Mathematics Literacy and Problem Solving: PISA 2003 Results from the U.S. Perspective." 2005. Pp. 15 and 29. Available at: http://nces.ed.gov/pubs2005/2005003.pdf.

[23]The Business Roundtable. "Innovation and U.S. Competitiveness: Addressing the Talent Gap. Public Opinion Research." January 12, 2006. Available at: http://www.businessroundtable.org/pdf/20060112Two-pager.pdf.

[24]American Academy of Pediatrics. "Television—How it Affects Children." Available at: http://www.aap.org/. The American Academy of Pediatrics reports, "Children in the United States watch about four hours of TV every day"; this works out to be 1,460 hours per year.

[25]National Center for Education Statistics. 2005. "The Condition of Education." Table 26-2, Average Number of Instructional Hours per Year Spent in Public School, by Age or Grade of Student and Country: 2000 and 2001. Available at: http://nces.ed.gov/. NCES reports that in 2000 US 15-year-olds spent 990 hours in school, during the same year 4th graders spent 1,040 hours.

[26]National Center for Education Statistic. "Public Elementary and Secondary Students, Staff, Schools, and School Districts: School Year 2003-04." 2006. Available at: http://nces.ed.gov/.

[27]Analysis conducted by the Association of American Universities. 2006. "National Defense Education and Innovation Initiative." Based on data in National Science Board. *Science and Engineering Indicators 2004*. NSB 04-01. Arlington, VA: National Science Foundation, 2004. Appendix Table 2-33. For countries with both short and long degrees, the ratios are calculated with both short and long degrees as the numerator.

[28]National Science Board. *Science and Engineering Indicators 2004*. NSB 04-01. Arlington, VA: National Science Foundation, 2004. Chapter 2, Figure 2-23.

[29]National Science Board. A companion to *Science and Engineering Indicators 2004*. NSB 04-01. Arlington, VA: National Science Foundation, 2004.

[30]G. Gereffi and V. Wadhwa. 2005. "Framing the Engineering Outsourcing Debate: Placing the United States on a Level Playing Field with China and India." Available at: http://memp.pratt.duke.edu/downloads/duke_outsourcing_2005.pdf.

[31]Ministry of Science and Technology (MOST). *Chinese Statistical Yearbook 2004*. People's Republic of China: National Bureau of Statistics of China, 2004. Chapter 21, Table 21-11. Available at: http://www.stats.gov.cn/english/statisticaldata/yearlydata/yb2004-e/indexeh.htm. The extent to which engineering degrees from China are comparable to those from the United States is uncertain.

[32]National Association of Software and Service Companies. *Strategic Review 2005*. National Association of Software and Service Companies, India, 2005. Chapter 6, Sustaining the India Advantage. Available at: http://www.nasscom.org/strategic2005.asp.

[33]National Center for Education Statistics. *Digest of Education Statistics 2004*. Washington, DC: Institute of Education Sciences, Department of Education, 2004. Table 250. Available at: http://nces.ed.gov/.

[34]M. Boylan. Assessing Changes in Student Interest in Engineering Careers Over the Last Decade. CASEE, National Academy of Engineering, 2004. Available at: http://www.nae.edu/; C. Adelman. *Women and Men on the Engineering Path: A Model for Analysis of Undergraduate Careers*. Washington, DC: US Department of Education, 1998. Available at: http://www.ed.gov. According to this Department of Education analysis, the majority of students who switch from engineering majors complete a major in business or other non-science and engineering fields.

[35]National Center for Education Statistics. *Digest of Education Statistics 2004*. Washington, DC: Institute of Education Sciences, Department of Education, 2004. Table 250. Available at: http://nces.ed.gov/.

[36]S. Stuart. "2004 CEO Study: A Statistical Snapshot of Leading CEOs." 2005. Available at: http://content.spencerstuart.com/sswebsite/pdf/lib/Statistical_Snapshot_of_Leading_CEOs_relB3.pdf#search='ceo%20educational%20background'.

[37]US research and development spending in 2001 was $273.6 billion, of which industry performed $194 billion and funded about $184 billion. National Science Board. *Science and Engineering Indicators 2004*. NSB 04-01. Arlington, VA: National Science Foundation, 2004. One estimate of tort litigation costs in the United States was $205 billion in 2001.

J. A. Leonard. 2003. "How Structural Costs Imposed on U.S. Manufacturers Harm Workers and Threaten Competitiveness." Prepared for the Manufacturing Institute of the National Association of Manufacturers. Available at: http://www.nam.org/.

[38]US Patent and Trademark Office. "USPTO Annual List of Top 10 Organizations Receiving Most U.S. Patents." January 10, 2006. Available at: http://www.uspto.gov/web/offices/com/speeches/06-03.htm.

[39]CERN. Internet Homepage. Available at: http://public.web.cern.ch/Public/Welcome.html.

[40]American Association for the Advancement of Science. "Trends in Federal Research by Discipline, FY 1976-2004." October 2004. Available at: http://www.aaas.org/.

[41]Centers for Medicare and Medicaid Services. "National Heath Expenditures." 2005. Available at: http://www.cms.hhs.gov/NationalHealthExpendData/downloads/tables.pdf.

[42]US Department of Education, Office of the Secretary. *Meeting the Challenge of a Changing World: Strengthening Education for the 21st Century*. Washington, DC: US Department of Education, 2006.

[43]K. Wallace. "America's Brain Drain Crisis Why Our Best Scientists Are Disappearing, and What's Really at Stake." *Readers Digest,* December 2005.

[44]L. V. Gerstner, Jr. *Teaching at Risk: A Call to Action*. New York: City University of New York, 2004. Available at: www.theteachingcommission.org.

[45]Remarks by J. R. Immelt to Economic Club of Washington as reported in Neil Irwin. *US Needs More Engineers, GE Chief Says*. Washington Post, January 23, 2006.

[46]C. Barrett. Comments at public briefing on the release of Rising Above the Gathering Storm report. October 12, 2005. Available at: http://www.nationalacademies.org/morenews/20051012.html.

[47]B. Gates. Speech to the National Education Summit on High Schools. February 26, 2005. Available at: http://www.gatesfoundation.org/MediaCenter/Speeches/BillgSpeeches/BGSpeechNGA-050226.htm.

[48]W. J. Clinton. Commencement address at Morgan State University in Baltimore, Maryland. In *1997 Public Papers of the Presidents of the United States, Books I and II*. Washington, DC: Government Printing Office, May 18, 1997. Available at: http://www.gpoaccess.gov/pubpapers/wjclinton.html.

[49]Remarks by President George W. Bush in meeting with high-tech leaders. March 28, 2001. Available at: http://www.whitehouse.gov/.

Senator ALEXANDER. Thank you.

The CHAIRMAN. Thank you very much.

We were instructed that there will be no questions. And——

Senator ALEXANDER. Well, you——

The CHAIRMAN. Well, your presentation was so intimidating, I don't think you would have gotten any. Thank you, Senator Alexander, very much.

Senator ALEXANDER. Thank you, Mr. Chairman.

The CHAIRMAN. I'll go back to the regular order here. We're here today to discuss one of the government's most visionary functions, the funding of basic scientific research. The question is, do we have the guts and the political will to so do? Everyone in the room may already be aware of this, but it's worth repeating that the Federal Government funds nearly one-third of all research and development in the United States, and that includes 60 percent of all academic research.

Federal funding of basic research, those studies that give us the building blocks for new technologies and industries is part of a pipeline that supports the U.S. economy and our global competitiveness.

Now we know the results of basic research are inherently unpredictable. It's very hard to determine what investments will create the next economic miracle. But while the private sector sometimes avoids high-risk research that may only provide a return on investment over a very long period of time, the—or may provide little or no return, the government has, therefore, stepped into the breach.

These Federal investments have allowed the best ideas to develop our knowledge of the world and to create billion-dollar industries. These investments led to GPS, as the Senator indicated; biotechnology; 3-D printing; and the Internet. They have supported multibillion-dollar companies that are global household names. They also continually support the creation of new businesses across the country, which the Science Coalition tracked in their latest report, Sparking Economic Growth, which is this, it's a little bit smaller than what Senator Alexander held up. I encourage you to read it.

These investments continue to help train our science, technology, engineering, and mathematics workforce. And without these investments, we won't have the next generation of researchers; we won't have the next biotechnology industry; we won't have the next Internet. What we will have is a stagnant economy.

Looking at the debate that we're having in Congress about funding the government, well, that's where we're headed. The reckless shutdown has eroded confidence in the United States as a steadfast supporter of science. Researchers at our world's leading labs were told to go home, including several Nobel Laureates and grants were delayed when 99 percent of the National Science Foundation was furloughed. Stunning.

The shutdown was sudden, and it was harmful, yes; but the ongoing sequester is slowly but surely wearing away at the foundation of U.S. scientific research. The sequester got a little bit lost in the recent debates, et cetera, but the sequester is the long-term enemy. It's inexorable unless it gets eliminated.

Sequestration's indiscriminate cuts are costing us very dearly. The National Science Foundation took a $356 million cut in the past Fiscal Year. And that number will continue to go down again under the continuing resolution. That means fewer grants, less support for young researchers, and even scientists moving their work abroad. It's only going to get worse if we don't fix the sequester and continue to invest in our world-class scientists. It will just continue to get worse.

Our competitors know that basic research is worth the investment. And while we constrain ourselves; they are spending more, and they are catching up. That's why instead of retreating in the face of competition, we passed the America COMPETES Act in 2007, and the reauthorization in 2010, with the direction to double the funding of the National Science Foundation, major research accounts at the National Institute of Standards and Technology, and the Department of Energy's Office of Science.

I will again push for the reauthorization of this important piece of legislation. It may be the most important question we face in this committee. I yield to the distinguished Ranking Member.

STATEMENT OF HON. JOHN THUNE, U.S. SENATOR FROM SOUTH DAKOTA

Senator THUNE. Thank you, Mr. Chairman, for holding the hearing today to evaluate scientific research and development and STEM education initiatives under the America COMPETES Act authorizations. And I, like you, was pleased to welcome Senator Alexander to today's hearing.

It was a good opportunity to discuss the impact that R&D funding has on each of our states and on the U.S. economy overall. I believe it's important to remember our current budget realities and the need to set Federal funding priorities in scientific research and continue to improve coordination.

And I know that Senator Alexander has worked closely alongside, you, Mr. Chairman, and former Ranking Member Kay Bailey Hutchison on the America COMPETES Act of 2007 and 2010. And we appreciate, again, his participation today to provide us with a history of those legislative efforts.

The America COMPETES Acts of 2007 and 2010 have served as the authorizing vehicles for the National Science Foundation and the National Institute of Standard and Technology under our committee's jurisdiction, as well as for the Department of Energy, Office of Science.

The NSF is the primary source of Federal funds, funding in fields such as mathematics and computer science. Researchers in my home State of South Dakota, as well as other states represented by members of the Committee, benefit from NSF's Experimental Program to Simulate Competitive Research, EPSCoR, a program that is aimed at avoiding undue concentration of research in certain States and improving R&D competitiveness and STEM education throughout the United States.

Another agency of committee jurisdiction, NIST, carries out its mission of promoting U.S. innovation in industrial competitiveness by supporting research in fields such as engineering and information technology at NIST Laboratories in collaboration with private sector industry.

The Committee has looked to NIST this year with particular interest on the issue of cybersecurity, passing a bipartisan bill earlier this year that would authorize NIST to facilitate the development of a voluntary set of standards and best practices to reduce cyber risk to critical infrastructure.

And, as we will examine more closely next week when Secretary Pritzker is before us, NIST is also seeking to bridge the gap between cutting edge research and advanced manufacturing.

DOE's Office of Science is the lead Federal agency supporting fundamental scientific research for energy and the largest Federal supporter of basic research in the physical sciences. DOE, along with NSF, has supported cutting-edge physics research at the world class Sanford Underground Research Facility in Lead, South Dakota.

At SURF, as we refer to it, and as Dr. Perlmutter appreciates more than most, physics researchers are leading the Large Underground Xenon or LUX experiment a mile underground in the former Homestake Gold Mine in an effort to detect the existence of dark matter. Just last week researchers announced results from the experiment's first run, indicating that it is the most sensitive and capable dark matter detector in the world and making SURF scientists more likely to discover dark matter than anyone else.

The LUX experiments and other experiments at SURF search for answers to some of our most fundamental science questions and present a significant opportunity for U.S. leadership in the area of physical sciences as prioritized by the earlier America COMPETES Acts.

Federal support for basic research reflects a consensus that such research is the foundation for many innovations. Many have argued that closer cooperation among industry, government, and academia could further stimulate innovation, lead to new products and processes, and expand markets for U.S. businesses.

Along these lines, while I appreciate the importance of foundational science and basic research, I also look forward to hearing from our witnesses today about ways to improve technology transfer and commercialization of federally funded research, as well as some of the successful discoveries stemming from Federal research dollars.

Finally, I look forward to hearing from our witnesses about their ideas on how to improve STEM education, as well as their views on the challenges that affect our global competitiveness in the STEM professional fields.

Mr. Chairman, thanks again for this hearing.

I want to thank those that are going to be on our panels. And we look forward to hearing their insights. Thank you.

The CHAIRMAN. Thank you, sir.

So the second panel will come forward, please. That would be Dr. Kelvin Droegemeier. And he is Vice Chair—well, I'll introduce you—no. Have a seat. I'll introduce you just before you speak, OK?

Dr. Droegemeier is Vice Chairman of the National Science Board and Vice President for Research, and a Regents' Professor of Meteorology at the University of Oklahoma.

And if you are ready, sir, we will turn it over to you.

STATEMENT OF DR. KELVIN K. DROEGEMEIER, VICE PRESIDENT FOR RESEARCH, REGENTS' PROFESSOR OF METEOROLOGY AND WEATHERNEWS CHAIR EMERITUS, UNIVERSITY OF OKLAHOMA, AND VICE CHAIRMAN, NATIONAL SCIENCE BOARD

Dr. DROEGEMEIER. Thank you, Mr. Chairman.

Good afternoon, distinguished members of the Committee.

Ranking Member Thune, it's my great privilege to testify before you today.

As you said, I am a member of the faculty at the University of Oklahoma and also the Vice Chairman of the National Science Board. And I will be testifying in capacity as Vice Chairman today.

I just want to make three very brief points for you this afternoon. The first point is about basic research. And it's something that we perform as humans because of our innate desire to really understand the depths of the world in which we live. And it's really the DNA from which new innovations and technologies are created to fuel our economy.

Basic research has created thousands of discoveries. And very much like DNA, it can be assembled, it can be put on hold for a while, it can be restructured, and it can be brought back and reworked to create a variety of literally thousands, literally tens of thousands of technologies from which we will derive direct benefit. Without basic research, we have no foundation upon which to build.

My second point concerns something that Senator Alexander mentioned a moment ago, and that is that returns on basic research are often unpredictable and are often times very uncertain, and they take sometimes years to materialize. As a consequence, the Federal Government has a very important central role in supporting that research because it really is too risky for private companies that are looking to make their next quarter statement or the next half-year statement.

And President Roosevelt's science advisor, Vannevar Bush, when he suggested the creation of the National Science Foundation understood this point, that the Federal Government really has to be out there on the bleeding edge of funding very creative endeavors, that may, in fact, as the Chairman mentioned a moment ago, really have no immediate practical benefits for society.

The role of the National Science Foundation is quite unique because it is the only Federal agency that funds basic research across all disciplines of science and engineering, including the social, behavioral, and economic sciences. It also funds research infrastructure. It funds education and training of the next generation of scientists and engineers. And very importantly it supports activities that broaden the participation of traditionally underrepresented groups and it promotes partnerships in a variety of ways.

Continuing that point, I want to point out that the impacts of basic research on our economy sometimes may be difficult to pin down, but they're unmistakable. And I tell you, Senator Alexander did such a beautiful job of describing that. And there are so many situations where we can point to these tremendous things that make our lives more efficient and make our Nation more secure.

But there's one other point I want to bring out that I think is sometimes overlooked, and that is, basic research allows to us to prepare for the unexpected. 9/11 is a great example. Basic research really takes a very methodical approach to studying things, reproducing experiments to make sure the results are right. But when something like 9/11 happens, we don't have the luxury of time. We have to draw from our quiver of capabilities, pull them together very quickly, and start saving lives, protecting the war fighter, and protecting our country. That is what basic research allows us to do is be prepared for the unknown.

My final point concerns the word competition. We talk about the American Competitive Act and the initiative. And what does it mean to be competitive? I'm from Oklahoma. We play a lot of football down there. We like to be competitive. And I can tell you in sports, if you want to win, you have to be competitive. You can't possibly win if you're not competitive.

So in order for this Nation to be globally competitive, we have to be effective in our basic research. Many, many studies show, as Senator Alexander eloquently said, that we're losing our global competitiveness. And in fact, that was really why the other COMPETES Act was created.

And I will end by just saying, and Senator Rockefeller, I know you understand EPSCoR quite well, and Senator Thune, as well; but we know how to be competitive in this Nation. And EPSCoR is a great example. It's called the Experimental Program to Stimulate Competitive Research. It began about 33 years ago. And its sole focus is to help states that are traditionally not competitive, for Federal funding and particularly at NSF, to develop their infrastructure, their capabilities so they can be competitive.

And many of the states that have received EPSCoR funding have increased their competitiveness by nearly 50 percent, and that means they're becoming more competitive, they're contributing more to the science enterprise in this Nation. And we have lots of examples that I could cite to show you the very tremendous value of the EPSCoR program. And so I just want to say that we, as a nation, know to compete and there's perfect proof for that in EPSCoR.

And finally, as Senator Alexander noted, this is a very challenging time for Federal budgets and for basic research, but truly if we lose sight of supporting this fundamental foundational activity that truly can trace back to all of the important activities and devices and resources that improve our quality of life, make our Nation safe, make us effective as a society; if we lose that foundation, then we have nothing truly upon which to build.

So ultimately basic research allows us to control our destiny. And as the greatest nation on Earth, that's extremely important. On behalf of the National Science Board, I want to thank you for your incredibly strong and generous support of basic science, and for the National Science Foundation. We all look forward to continuing to work with you in this very productive relationship in our service to our Nation.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Droegemeier follows:]

PREPARED STATEMENT OF DR. KELVIN K. DROEGEMEIER, VICE PRESIDENT FOR RESEARCH, REGENTS' PROFESSOR OF METEOROLOGY AND WEATHERNEWS CHAIR EMERITUS, UNIVERSITY OF OKLAHOMA; VICE CHAIRMAN, NATIONAL SCIENCE BOARD

I thank Chairman Rockefeller, Ranking Member Thune, and Members of the Committee for the privilege of testifying on the important role played by science and engineering research and education in our Nation's competitiveness. My name is Kelvin Droegemeier and I am Vice President for Research, Regents' Professor of Meteorology, and Weathernews Chair Emeritus at the University of Oklahoma. I also am a member of the National Science Board (NSB, Board), which establishes policy for the National Science Foundation (NSF) and serves as an independent body of advisors to both the President and Congress on matters related to science and engineering research and education. I am testifying today in my role as NSB Vice Chairman.

On behalf of the Board, I thank the Members of this committee for their longstanding commitment to fostering national prosperity, economic security, quality education, and international competitiveness through support for basic research in science, technology, engineering and mathematics (STEM).

An important component of this commitment has been the America COMPETES Act.

Enacted in 2007 and reauthorized in 2010, the Act provided a framework for catalyzing research in areas of national priority and for coordinating Federal STEM education efforts. At NSF, the Act enabled continued investment in our Nation's scientific infrastructure, innovation in STEM education, and development of a portfolio of research investments that respond to current national challenges while laying the foundation for a robust scientific and technological enterprise into the mid-21st century. It also promoted excellence in scholarship via training in the responsible conduct of research, and the mentoring of post-doctoral researchers.

1. NSF and the Importance of Basic Research

The idea for NSF arose in the wake of the Second World War. President Roosevelt, recognizing that wartime cooperation between the Federal Government and scientific community had contributed to the U.S. victory, asked his *de facto* science advisor, engineer Dr. Vannevar Bush, to develop a report describing how the Government could promote scientific progress in the postwar period. That report, *Science—The Endless Frontier,* called for the creation of NSF and stressed the *essential role of the Federal Government* in cultivating the Nation's "scientific talent" and in *funding basic research.*

Basic research, which represents structured inquiry motivated by the innate human desire to understand the fundamental behavior of the world in which we live, is the DNA from which new innovations and technologies arise to fuel our Nation's economy. That DNA, representing thousands of discoveries across all disciplines, can be assembled, refined, set aside for a time until other advances call upon it, and re-used in an almost infinite number of ways to produce outcomes that have profoundly positive benefits for society. Bush argued that investments in basic research were essential to American national security and competitiveness, and that same wise notion was the foundation of the COMPETES Act and is the principal reason NSF is featured prominently within it.

NSF funds the highest quality projects having the potential to advance, if not transform, the frontiers of knowledge and advance societal goals. Two criteria, "Intellectual Merit" and "Broader Impacts," shape the NSF merit review process, which is viewed as the gold standard worldwide. NSB recently re-examined these criteria to ensure that NSF maximizes the public's return on investment.

2. The U.S. Research and Innovation Ecosystem and NSF's Role in it

Basic research, applied research, and development in the U.S. are dominated by development activities—78 percent of which are funded by the private sector. Private industry also is the largest source of funding for applied research. In this context, the Federal Government, and NSF in particular, play a critical, complementary role by supporting *basic research,* the majority of which is performed at our Nation's colleges and universities. Private industry relies on the new knowledge created by basic research to develop new and innovative products and services.

Because the returns on investments in basic research are unpredictable and may take years, if not decades, to materialize, the private sector understandably invests relatively little money in it. Consequently, as noted by Vannevar Bush, the Federal Government has an *essential role* in supporting basic research. NSF's role in particular is *unique* because it is the only agency that funds basic research and education across all STEM disciplines (excluding clinical medical research) and (presently) at all levels of STEM education.

3. Samples of Economic and Societal Returns on Investment in Basic Research

For over 60 years, with the support of Congress, NSF has been funding basic research, enabling our Nation to become the undisputed world leader in science and technology. As noted previously, linking basic research outcomes to innovated products and services can be difficult because the path from the former to the latter is often indistinct, sometimes evolving over long periods of time and integrating elements from multiple disciplines and technologies. However, examples large and small abound and are important for demonstrating the value of basic research to, and the thoughtful investment of tax dollars toward achieving, national competitiveness. A few are provided below.

- NSF-funded mathematicians have re-applied algorithms that predict earthquake aftershocks and created a crime prediction model. After police implemented the crime prediction model in Los Angeles' Foothill precinct (300,000 residents), *crime decreased 12 percent* relative to surrounding areas.
- Almost 20,000 kidney transplants are conducted each year in the U.S. Based on their knowledge of game theory and market dynamics, NSF-funded economists developed an algorithm that facilitates kidney matching for patients who have willing but biologically incompatible donors. The *number of transplants* performed through paired exchanges has risen dramatically: *from 2 in 2000 to 443 in 2012.*
- Coronary artery disease, the major cause of heart attacks, annually afflicts more than 700,000 Americans and costs the Nation nearly $110 billion to treat annually. NSF-funded researchers developed mathematical tools to better understand and control interactions between arterial walls and blood flow. Subsequently, scientists improved stents to help open narrowed arteries and later formed a biotechnology company that is publicly traded on NASDAQ and currently has a value of nearly *$950 million.*
- As part of its start-up funding, Qualcomm received a Small Business Innovation Research award from NSF. Over 21,000 employees and 170 locations later, this company has forever changed the face of digital wireless telecommunications products and services. Qualcomm is now worth more than *$100 billion.*

One often overlooked aspect of basic research is that it helps our Nation be prepared for the unexpected. When confronted with entirely new challenges, time often does not exist to conduct the thoughtful, intensive studies associated with basic research. Consequently, having research outcomes in hand is essential. Nowhere is this more evident than in current and rapidly evolving national security challenges, where results from previous basic research in image processing, electro-chemical sensing, and data mining have led to the rapid creation of field-deployed technologies for enhancing security in airports, better ensuring the safety of the war fighter, and fighting new generation cyber attacks.

These and thousands of other examples—which show how basic research in science and engineering leads to practical benefits via innovation—directly impact the ability of the U.S. to be competitive in a global society: competitive economically, competitive in education, competitive technologically, and also secure. Consequently, by virtue of its unique mission, NSF funding of basic research continues to be central to U.S. competitiveness.

Another important and easily overlooked aspect of basic research is the talent pool needed to perform it in our Nation's colleges and universities, and to innovate with its outcomes in the private sector. STEM education is the *sine qua non* for this workforce and is a foundational component of NSF's portfolio. Without it, and without efforts to ensure a diverse workforce that draws upon and reflects the increasingly diverse structure of our Nation, the competitiveness of the U.S. will suffer immeasurably.

4. Toward a Globally Competitive Nation

What does it mean to be competitive? In sports, business, and the military, one cannot *win* unless one is competitive. The U.S. must be globally competitive in order to be a world leader—in research, technology, advanced manufacturing, educational attainment, private sector innovation, public-private partnerships, economic prosperity, and quality of life. Unfortunately, numerous metrics and studies show that the U.S. is rapidly losing its competitiveness.

According to a 2012 report[i] by the U.S. Department of Commerce, the strengthening economies of several countries around the world are posing a competitive challenge for the U.S. The ability of the U.S. to create jobs has slipped, and it has made little progress in competitiveness during the past 2 decades, now ranking fourth in the world in innovation-based competitiveness. The preparation of U.S. students in math and science is notably problematic, with 17 Organization for Economic Co-operation and Development (OECD) countries ranked above the U.S. Numerous equally sobering statistics exist and are readily available. NSF is vitally important in restoring U.S. competitiveness by building competitive capacity in many ways.

First, as noted previously and via a wide array of programs across all disciplines, NSF funds basic research at the frontiers of discovery and thus creates new knowledge—the DNA of innovation. Many of NSF's activities focus on areas of national priority and thus lie at the heart of national competitiveness. These include, at the present time, advanced manufacturing, robotics and cyber-physical systems, interdisciplinary research to enrich our understanding of the brain's neural networks, nanotechnology, STEM education, global change research, and cybersecurity research and development.

Second, NSF funds the construction of modern research infrastructure that is critical to maintaining U.S. technological competitiveness. Through its Major Research Equipment and Facilities Construction (MREFC) account, NSF provides our Nation's scientists and engineers with the powerful, large, complex tools necessary to perform world-class research. This includes—but is not limited to—telescopes, supercomputing facilities, ships, airplanes, and large arrays of observing systems for long-term sampling of the planet below ground, at the surface and in the atmosphere. Other programs, such as Major Research Instrumentation (MRI), provide funding to colleges and universities to both develop and acquire large pieces of equipment for research and education, with the responsibility for long-term sustainability borne by the receiving institution.

Third, NSF facilitates the education and training of the next generation of scientists and engineers (graduate and undergraduate students as well as post-doctoral researchers) by funding grants to support their research and training. Flagship programs such as the NSF Graduate Research Fellowship, which has produced several Nobel Laureates over the past 6 decades, are seminal to U.S. competitiveness and STEM workforce development. The longstanding NSF CAREER program, which funds early-career faculty, is critical for ensuring that the most outstanding new academic researchers get off to a strong start and begin making seminal contributions as soon as possible.

Fourth, NSF supports numerous programs to broaden the participation of traditionally underrepresented populations in STEM fields. This is an extremely important challenge for U.S. competitiveness in light of rapidly shifting national demographics, as well as the substantial intellectual talent that goes untapped when underrepresented individuals either leave STEM fields or fail to select them to begin with. Although progress is being made, it is far slower than needed for the U.S. to amass a STEM talent pool to ensure future competitiveness.

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[i] U.S. Department of Commerce, 2012: The Competitiveness and Innovation Capacity of the United States. Available at *http://www.commerce.gov/sites/default/files/documents/2012/january/competes_010511_0.pdf*

Fifth, NSF has undertaken efforts recently in partnership with the private sector, via its Innovation Corps (I-Corps) program, to play a direct role in the innovation process. Specifically, I-Corps is a set of activities and programs that prepare scientists and engineers to extend their focus beyond the laboratory and broadens the impact of select, NSF-funded, basic-research projects. Although knowledge gained from NSF-supported basic research frequently advances a particular field of science or engineering, some results also show immediate potential for broader applicability and impact in the commercial world. Such results may be translated through I-Corps into technologies with near-term benefits for the economy and society. Combining experience and guidance from established entrepreneurs with a targeted curriculum, I-Corps teaches grantees to identify valuable product opportunities that can emerge from academic research, and offers entrepreneurship training to student participants.

And finally, NSF's Small Business Innovation Research (SBIR) program, as another example, provides seed money for high risk, high reward private sector ventures. NSF recently conferred an SBIR award that has the potential to lead to widespread recycling of the wastewater produced in the process of natural gas extraction known as "fracking."

5. The Experimental Program to Stimulate Competitive Research (EPSCoR): A National Role Model for Capacity-Building and Enhancing Competitiveness

NSF is mandated by statute to ensure that all geographic regions in the U.S. contribute to science and engineering research and education via NSF support, and as a consequence play a meaningful role in U.S. competitiveness. A program foundational to achieving this goal is the Experimental Program to Stimulate Competitive Research (EPSCoR), which provides *research capacity-building funding,* based upon competitively-reviewed proposals, to states (formally known as jurisdictions) which historically have received comparatively small percentages of NSF support. At the present time, 31 jurisdictions are eligible for NSF support, and other agencies, including the National Aeronautics and Space Administration (NASA) and Department of Energy (DOE), have EPSCoR programs.

The current NSF budget for EPSCoR is approximately $160 million per year and is directed to a variety of programs designed specifically to build research capacity. The flagship program, known as Research Infrastructure Improvement (RII, Track-1), provides up to $20 million for 5 years to support areas of *strategic research importance* for jurisdictions based upon their state science and technology plans, most commonly in alignment with national research priorities. Multi-jurisdictional activities are becoming more common as a means for leveraging capability for addressing larger, more complex challenges. Additional leveraging occurs via mandated cost sharing from the jurisdictions themselves.

Since the program's inception in 1980, competitiveness of EPSCoR jurisdictions (which entered the program in four cohorts) has increased by as much as 41 percent. Topics addressed range from bioinformatics and climate adaptation to nanotechnology and STEM education. EPSCoR funding also builds capacity in cyberinfrastructure in ways strategically aligned with national research and education priorities.

In addition to building capacity for basic research, EPSCoR plays an important role in economic development. As one of many examples, in my own state of Oklahoma, EPSCoR funding helped support one of the first NSF Science and Technology Centers in 1989, which I directed at the University of Oklahoma. This center pioneered a new science of computer-based prediction of thunderstorms, leading to the founding of a private weather technology company that now employs more than 80 people. Outcomes from this research are being transitioned into operations within the U.S. National Weather Service and hold promise for increasing the lead time for tornado warnings from 15 minutes to over an hour.

Additionally in Oklahoma, nanotechnology research funded by NSF EPSCoR played a role in the creation of a private engineering company that established the national standard (National Institute for Standards and Technology—NIST) for purity of single-walled carbon nanotubes—an essential element in hundreds of products. More than 20 nanotechnology companies are now located in Oklahoma, catalyzed in part by the EPSCoR investment. Additionally, more than 12,000 K–12 students, 1,800 teachers, 7,000 university students, 2,000 university faculty, and 59 businesses in Oklahoma have been served directly by EPSCoR education and outreach programs during the past five years.

Similar examples can be found for other EPSCoR jurisdictions. In Montana, substantial growth in academic research programs is credited with increasing the number of high technology companies from 17 to 175. In Idaho, it is estimated that every

Federal dollar invested in EPSCoR programs has yielded $18 to the local economy. In Louisiana, nearly 22 percent of students supported by EPSCoR have come from underrepresented groups. And in Wyoming, research investments by EPSCoR helped position the state to host a major supercomputing center for the National Center for Atmospheric Research, which is catalyzing new research, education and technology development activities across the entire region.

6. Summary and Closing Thoughts

More than 60 years after its establishment, NSF remains a crucial component in the engine of U.S. innovation, competitiveness, and security. The agency's work is more vital than ever because science now has bearing on almost every aspect of our lives, from national security and global economic competitiveness to our health, quality of life and future workforce needs. NSF-sponsored research continues to open new frontiers by balancing NSF's longstanding "grass roots" vision of science with an agency-wide commitment to fund research addressing national priorities.

NSF's work in STEM education remains vital to ensuring that America's students, workers, and scientists remain competitive in the globally connected world. Although the context in which NSF operates today differs markedly from the post-World War II and Cold War worlds out of which it arose, the necessity of Government support for basic scientific research, for research infrastructure, and for educating the next generation of researchers remains as true today as in 1950. Then as now, basic research catalyzes the scientific and technological ecosystem. Then, as now, neither industry nor academia alone could make sufficient investments in basic science to sustain national competitiveness and security.

This is a difficult time for Federal budgets and for individuals in the academic, nonprofit and public sectors who rely on Federal support. Investments in science and technology compete with a host of other legitimate funding priorities. As other countries emulate our success by building their innovation infrastructures, we must be vigilant in sustaining our own innovative capacity. NSF remains committed to making the hard decisions needed to ensure that its portfolio obtains the greatest return on investment and maximizes the benefits of taxpayer support.

On behalf of the National Science Board, I thank you for your support of the National Science Foundation. We look forward to continuing our productive working relationship with you in service to the Nation.

The CHAIRMAN. Thank you, sir.

Might I just suggest to staff that are present that it would be really kind of nice if we had more members here.

[Laughter.]

The CHAIRMAN. And therefore, please go to work on that. I can't command one side, but I can command the other side.

[Laughter.]

Senator COATS. And I was just getting ready to leave.

The CHAIRMAN. I know. I caught you, Dan.

Senator COATS. I——

The CHAIRMAN. I caught you.

Senator COATS.—feel very guilty, but——

The CHAIRMAN. Yes.

Senator COATS.—I do have a——

The CHAIRMAN. Well, you're a special person, so——

[Laughter.]

The CHAIRMAN. But I did embarrass him, didn't I? Just a bit.

All right. Now Dr. Saul Perlmutter, who is a Professor of Physics at the University of California at Berkeley, a Senior Scientist at the Lawrence Berkeley National Laboratory, and a 2011 Nobel Laureate in physics.

Welcome, sir, we're honored by your presence.

STATEMENT OF DR. SAUL PERLMUTTER, PROFESSOR OF PHYSICS, UNIVERSITY OF CALIFORNIA, BERKELEY; SENIOR SCIENTIST, LAWRENCE BERKELEY NATIONAL LABORATORY

Dr. PERLMUTTER. Thank you.

All right, Chairman Rockefeller, Ranking Member Thune, and distinguished members of the Committee, thank you for inviting me today.

I thought it might be helpful to begin with a few words about the science I've been involved in since it provides a good example for many of the issues that this committee is addressing. Initially we set out to measure how much gravity was slowing the expansion of the universe. And after 10 years of hard work, we made a surprising discovery, the expansion of the university isn't slowing down at all, it's actually speeding up, the universe is expanding faster and faster and we have no idea why.

This mystery has grabbed the attention of scientists around the world, attracted new students to science, and triggered a tidal wave of scientific creativity with new theories, new technological inventions, and new computing methods, and of course it also ended up winning a Nobel Prize.

Is the accelerating expansion of the universe due to some previously unknown energy, we call it dark energy, that dominates the stuff of the universe; or alternatively, maybe we need to revise Einstein's theory of general relativity, his theory of gravity? This is clearly exciting science, but why should the government support such basic research? What's in it for the taxpayer?

First, it's exactly these sorts of exciting questions that attract the next generation to study science, engineering, and mathematics and then to go on to careers that use these skills in business and government and in academia.

Second, the challenges of basic science, which appeal to the—to a universal human curiosity, end up somehow almost magically being the source of our remarkable technological capabilities and then our economic strength.

For example, I mentioned the close connection between our surprising discovery and Einstein's theory of general relativity. What could be more arcane, less practical sounding than Einstein's theory? It deals with behavior of clocks traveling near the speed of light. And yet if you've ever tried to find your location with the iPhone in your pocket, you've relied on Einstein's theory. Without this basic science, the GPS locator on your flight into Reagan National Airport would miss the runway.

So I have no idea today what an understanding of the accelerating universe and dark energy will allow us to do, but Einstein could never have guessed that his theory would power this technology or the million-dollar GPS industry.

Third, the dividends from fundamental science benefit society at large and cannot be directed in advance to fulfill a particular commercial need. So, as was just mentioned, this is not a job for private investors. These investments are exactly the kind that the government is needed for.

Finally, my own work would never have happened without past investments by the U.S. Government. My early research was kicked off with NSF support. It never could have lasted those 10 years without the unique capabilities of a national laboratory and the patient support of the Department of Energy, which funds that lab. And in the end it depended on the space-based capabilities of NASA and its Hubble Space Telescope.

Our project then succeeded because there was a stable and robust network of agencies supporting fundamental research, an ecosystem of innovation. This is why the U.S. has dominated the Nobel Prizes and built a flourishing technologically-advanced economy.

How do we ensure the health of this fundamental science ecosystem so that it will drive the economic success for the next generation? How do we make it possible for a young scientist starting out today with a project like mine to make her Nobel Prize-winning discovery?

I'm concerned that if I were that scientist starting my project today, it wouldn't have happened. The trend lines in the U.S. for all fields of sciences are disturbing. Already our lack of investment in particle physics has moved its center of gravity to Europe. It's beginning to happen in my field of dark energy, as well, a field in which the Nation currently leads the world.

For the first time I have seen post-doctoral students choose positions abroad rather than the U.S. because they saw the future there. We live in times of breathtaking scientific opportunities, but America must stay in the game. We must invest again in the sciences and the basic sciences with the enthusiasm that we did before if we are going to stay competitive with Europe, China and Japan and the rest of the world, who are now redoubling their effort to build the scientific infrastructure they saw make us so successful.

Such basic science is the root to another prosperous century and a community of science and scientists that are ready to handle the challenges of that century.

Thank you.

[The prepared statement of Dr. Perlmutter follows:]

PREPARED STATEMENT OF DR. SAUL PERLMUTTER, PROFESSOR OF PHYSICS, UNIVERSITY OF CALIFORNIA, BERKELEY; SENIOR SCIENTIST, LAWRENCE BERKELEY NATIONAL LABORATORY

Chairman Rockefeller, Ranking Member Thune and distinguished Members of the Committee, thank you for the opportunity to testify before you today about the importance of science to our Nation and to the world. I am honored by the invitation and hope that my testimony may be helpful to you and your staff as you draft important legislation and make critical funding decisions that help to ensure the United States of America's scientific leadership. I believe that without scientific leadership, we will lose our leadership in technology and innovation. Without technological leadership, our economic and national security will be fundamentally weakened.

My name is Saul Perlmutter and I am a senior scientist at the Department of Energy Office of Science's Lawrence Berkeley National Laboratory and a Professor of Physics at the University of California, Berkeley. I am testifying today as a private citizen and not on behalf of Berkeley Lab or the University. My testimony today will explore these important issues:

1. Why curiosity-driven science is important and why we should care.
2. Why the whole of the United States' science enterprise—consisting of an interdependent ecosystem of agencies, universities, national laboratories and industry—is greater than the sum of its parts.

3. Why waning Federal support for curiosity-driven science is stagnating our science enterprise and weakening the Nation's innovation foundation—immediately threatening our international economic competitiveness and the prospects of a more peaceful and productive world.

Why curiosity-driven science is important

In 2011, I was awarded, along with two other scientists, the Nobel Prize in Physics for the discovery that the universe is expanding at an accelerating rate. This discovery came as a huge surprise to me, to my team and to the entire physics world. We had anticipated one of two outcomes: either the expansion would be slowing down, but still expanding forever; or that the universe was slowing so much that someday it would come to a halt, and then, collapse in on itself—both options due to the force of gravity.

Since our discovery in 1998, thousands of theories have been published that attempt to explain this extraordinary phenomenon. The most widely discussed idea is that an unknown energy fills all empty space and counteracts gravity's pull enough to fuel the universe's accelerating expansion. Scientists and the scientific media have dubbed this unknown entity "dark energy"—"dark" only to signify that we don't know what it is—and estimate that it makes up almost three quarters of the "stuff" of the universe. This is a remarkable prospect that begs further exploration—what is this stuff that makes up the majority of our universe.

Although the concept of "dark energy" is mindboggling, it would be even more earthshattering if the accelerating expansion is caused instead by a flaw in the laws of gravity, which were originally set down by Newton, and perfected by Einstein in his Theory of General Relativity. Gravity and its properties are considered well understood—down to many digits of certainty. Scientific and engineering understanding of gravity made the industrial revolution possible and ushered in the modern era. What if our current understanding is simply the first step in a much bigger and more complex theory?

Either way, scientists are energized to explore this cosmic mystery. These are questions that we must tackle. Curiosity drove our initial research and experiments—today, curiosity drives us to ask new questions and design new experiments to explore this cosmic riddle.

Why should the Federal Government fund this type of curiosity-driven research? It's not just because it is exciting, although it is. It's not just because this is exactly the type of science that attracts young people to science and engineering careers, although it is that too. It is primarily because, by broadening our base of knowledge and deepening our understanding of the world, we will provide our children with brighter, more peaceful futures, with more rewarding jobs, and longer lives. In a nutshell, scientific knowledge gives us the power to secure a better future.

I have no idea what the discovery of an accelerating universe will mean to the health of our economy and our ability to build a better and more peaceful world. Certainly, building experiments and tools, as we did, to measure our universe with greater and greater fidelity and efficiency has led to new and productive technologies, such as more sensitive CCD detectors that are now being used in health care. These spin-off technologies produce jobs and create economic activity. But, even more importantly, no one can credibly claim to know what wide-ranging benefits the discovery will ultimately have on society.

Pursuit of curiosity-driven science is not a luxury—it is the foundation of how real progress and societal advancement is made. Grand challenges that face our Nation and world require more than incremental, marginal solutions. Short-term, near-horizon research and development, also referred to as applied research, will not by itself lead to transformational advances. Applied research is certainly critical for moving solutions forward, but transformational leaps in technologies and in answers to tough problems don't happen without new discoveries that come from curiosity-driven science.

So although I don't know how my team's scientific accomplishments will affect society broadly, I do know that big discoveries make us stronger and more capable. I do know that the laser would not have been invented if your goal were to build a laser printer or perform laser surgery. The need for global positioning systems would not have spawned Einstein's Theory of General Relativity—a theory so apparently esoteric that it addresses questions such as "what happens to clocks traveling through space at speeds approaching the speed of light." I do know that quantum mechanics, the theory of how matter and energy behave at the atomic and subatomic levels, would not have been developed if you were building a medical imaging device or the iPhone. But, without the curiosity-driven science that led to the theory of quantum physics, we would not have MRIs, electron microscopes or the transistor, an invention underpinning the information technology world in which we now live.

I am certain that the discovery in 1998 of the accelerating expansion of the universe has and will make us a stronger nation and help to build a better and more peaceful world. But a discovery like this was not an easy task.

Our research began as a three-year project. Our energy level was high and our expectations were even higher. Ten long years later we finally presented the results that showed our universe was expanding at an accelerating rate. Our results and those of another research team sent the worldwide physics community reeling. We knew that it was a tough problem. We knew we had to invent brand new technologies that would help find the standard candles, a certain type of exploding star, a supernova, needed to make our measurements and plot our points. We knew this sort of experiment and analysis had never been done before. We didn't know it would take us as long as it did.

Fortunately we did not have the pressures placed on companies by vigilant investors eager for short-term returns. My team and I were researchers at a Department of Energy Office of Science national laboratory. There we were given the time, space and resources required to accomplish our mission and were supported by a commitment to world-class, leading-edge science.

Although it is a surprise to most people, DOE's Office of Science is the Nation's largest funder of the physical sciences—including the field of physics. The national laboratory provided me a supportive and uniquely well-suited place to conduct my research. The Office of Science, supported by the Federal Government, with a strong and unwavering commitment to world-leading science, has the patience, resources and institutions needed to consistently deliver groundbreaking scientific and technological advances—the type of advances that win Nobel Prizes and create new knowledge that leapfrogs current understanding.

Why the whole of the United States scientific enterprise is greater than the sum of its parts

My research is primarily supported by the DOE Office of Science, but from the beginnings of my graduate and postdoctoral education and training through today, I am most certainly a product of the Federal Government's investment in a wide range of agencies, research programs, universities and facilities. As an early career scientist, I received funding from the National Science Foundation for research at the Center for Particle Astrophysics at Berkeley. This early funding helped to hone my skills as a researcher, prepared me for a successful science career, and initiated my research. Likewise, funding from NASA has supported work throughout my tenure as a scientist by providing valuable time on the Hubble Space Telescope and NASA grants for research. Collaborations with universities, industry, and other national laboratories have been a constant and critical part of my research career. In other words, it may not take a village, but it does take an ecosystem to advance scientific and innovation progress.

As illustrated by my career, the Nation's science and innovation enterprise is underpinned by this complex ecosystem of people, ideas and tools. This scientific infrastructure, until recently, has been unmatched and has been the envy of the world. It grew out of a post-World War II commitment made by the Federal Government to support basic scientific research conducted at U.S. universities and national laboratories.

Our nation has never had a comprehensive science strategy. From time to time we marshal our scientific resources and talents to focus intently on certain large problems and opportunities, such as the Manhattan Project, the Race to Space and the Human Genome Project. But by and large, the development of our innovation enterprise has been an organic one, fueled by an entrepreneurial American spirit that embraces progress and always seeks to improve society by new knowledge and understanding.

People like Ernest Orlando Lawrence, the inventor of the cyclotron and the founder of Lawrence Berkeley National Laboratory, begged, borrowed, and otherwise obtained the resources needed to move science forward. In Lawrence's case he established a laboratory in 1931 on the campus of the University of California, Berkeley, that today is an international leader in basic science and energy technology development. Individuals like Lawrence, Fermi, Oppenheimer, and others, pushed the boundaries of knowledge and physics to aid in the Allied effort to defeat Nazism—in the process building the infrastructure and intellectual capacity that would lead to the national laboratory system. Other scientific, policy and political leaders worked tirelessly to establish the National Science Foundation and set its course as one of the greatest scientific grant-making organizations in the world. Miraculously, or serendipitously, these scientific initiatives, now agencies, and others, such as

NASA, DARPA, NIST and NIH, have developed collectively into a powerhouse ecosystem of innovation. The results have been spectacular. A basic, but telling, metric is that of all the Nobel Prizes awarded in the sciences, medicine and economics, 48 percent of the winners have been from the United States.

As in a natural ecosystem, each component of our research and development enterprise has a role to play—contributing to its vitality and sustainability. For example, it is widely accepted that health research conducted by the NIH is very important. Each of us has a personal story about how advances in medicine and health care have touched our lives, our families and our friends. However, without discoveries in the physical sciences—such as in physics and chemistry—many of the breakthroughs and leapfrog advances in health care will not take place. Better understanding of materials and organisms at the most fundamental atomic and molecular levels leads to new discoveries that find their way into new medicines and treatments. Unfortunately, this linkage and the symbiotic nature of our scientific enterprise is not obvious and certainly not mainstream knowledge. So, please indulge me as I take a moment to describe the roles of various participants in the Nation's innovation ecosystem. This description is not all-inclusive, but hopefully will provide a better sense of its nature and structure.

Universities

From the very beginning of our national history, universities have been centers of scientific inquiry and technology advancement. Referring to the 1862 founding of West Virginia University, a local paper wrote, "a place more eligible for the quiet and successful pursuit of science . . . is nowhere to be found." E.O. Lawrence, inventor of the cyclotron and founder of Berkeley Lab, graduated from the University of South Dakota in 1922—his grounding in the sciences there laid the foundation for remarkable contributions to science and society. Universities educate and train future scientists and engineers, like Lawrence, and host research in an open and encouraging environment.

Universities are the great scientific hot houses that provide fertile ground for scientific collaboration and exploration. Science is typically an intimate endeavor at universities with principal investigators working side by side with their team of students and postdoctoral colleagues, conducting cutting edge research with new ideas and great enthusiasm. It is an environment of opportunity and passion that is very hard to replicate and generally unique to the university setting. The NSF, NIH, DOE's Office of Science and other grant making agencies fund the best and brightest at our universities to conduct the most compelling research—research that neither industry, nor any other institution would have the means or will to fund.

National Laboratories

DOE's national laboratories, spawned from the Manhattan project and subsequently home to large teams of scientists and scientific resources, build and maintain unique, large-scale and world-leading research tools that are utilized broadly by university and industrial researchers. These tools, such as the Advanced Light Source at Berkeley Lab, the Spallation Neutron Source at Oak Ridge, and the Center for Nanoscale Materials at Argonne—over 30 facilities in total throughout the DOE complex—provide tens of thousands of American researchers access to critical scientific capabilities that help them to maintain the Nation's scientific leadership. These researchers come from both academia and industry; are funded by a host of Federal agencies, philanthropic organizations and companies; and come from every state in the union.

National laboratories, from their inception, have assembled and nurtured multidisciplinary teams of scientific experts to meet Federal needs and address national R&D priorities and challenges of scale. With a more focused and flexible organizational system than universities, national laboratories can more easily adjust to concentrate intellectual and capital resources on Federal mission needs and scientific advancement.

As mentioned previously, my research requires a broad team of astrophysicists, engineers, students, postdocs and others to accomplish its goals. These collaborations often include researchers from dozens of universities, other national laboratories and industry partners. Our accomplishments would not have been possible without this team approach and a national laboratory as the organizing and supporting institution.

Industry

Unfortunately, the days of the big industrial basic science laboratory are over. As the Department of Commerce's January 2012 report on "The Competitiveness and Innovative Capacity of the United States" expounded upon, investments in basic, curiosity-driven science don't pay out directly for commercial investors, whereas the returns for society are eventually large. Even so, industry still plays a different but important role in the innovation ecosystem.

Industry delivers technological advances to the marketplace and to society by making strategic, early investments in new technology. Businesses rely on scientific and engineering talent produced by universities and trained at national laboratories to meet their workforce needs and remain globally competitive. Through in-house applied research and by harnessing scientific advances and technology developed at universities and national laboratories, industry drives commerce and innovation. And, finally, researchers from industry utilize the unique scientific tools of the national laboratories to move technologies to the marketplace.

Why economic and national security are threatened by waning support for science

As a Nobel Laureate, I am constantly invited to events to launch new scientific initiatives and inaugurate or review new research programs. Unfortunately, the majority of these invitations are coming from other countries—China, South Korea, Germany, France, Saudi Arabia, Switzerland, etc.—not from the U.S. Although my experience is certainly anecdotal, the implications are backed up by real data. The data clearly shows how other nations are increasing their investments in basic science, unlike in the U.S. where support for and forward movement on basic science appears to be stagnating. Data supporting this may be found at *http://www.nsf.gov/statistics/seind12/c0/c0i.htm* and attached to this testimony.

My field of physics and astrophysics offers a cautionary tale about the effects of scientific stagnation on innovation leadership. With the demise of U.S. plans to build the Superconducting Super Collider in the 1993, and the corresponding rise of European leadership to build the Large Hadron Collider at CERN, the center of gravity for particle physics at the energy frontier moved from America to Europe. Now, instead of doing their research on American soil, U.S. science students, postdocs and early career scientists who study the Higgs boson and other high-energy particles are cutting their teeth in Europe.

Fortunately, in some physics fields, such as my field of study, astrophysics and cosmology—the study of the cosmos—the United States still maintains scientific leadership. But, that leadership, too, is threatened. Since shortly after the discovery of dark energy, my colleagues and I, and other research teams around the country, have proposed follow-up experiments, both large and small, in space and ground-based, to study dark energy with greater precision. Even with high rankings from agencies and the scientific community for each of these proposed experiments, interagency gridlock and now “no new starts” have left them in a state of almost suspended animation. Meanwhile the European Space Agency is moving ahead with plans to launch their own dark energy space mission, called Euclid, as early as 2020—seizing leadership in dark energy research. Research thrives on competition; we need to compete, not forfeit.

Some will argue that during periods of constrained budgets all Federal investments must be curtailed, cut back and reduced. Admittedly, there are always opportunities to find efficiencies and reduce costs. But, scrimping on science and holding up scientific progress, for whatever reason, is penny wise and pound foolish. Even in tough economic times and tight budgets it is possible to spend money wisely and make the investments necessary to reap a brighter future. The economic argument, though perhaps not immediately obvious to some, is singularly compelling. Yet, there is a broader and perhaps more important argument to be examined. Scientific advancement has made the world a better place—living standards are rising across the planet, fewer people are hungry and life spans are increasing. Science paves the way for a more peaceful and productive existence.

Yet, when trouble arises somewhere around the world or at home, whether natural or manmade, we must be prepared. Our response to natural and manmade disasters of the future will require sophisticated technologies yet invented. Threats may include comets or asteroids crashing to earth, volcanoes darkening the planet’s skies and, of course, the scourge of war. Today our Nation has a strong base of innovation and technological leadership because we have funded and nurtured the best curiosity-driven science portfolio the world has ever known. If we don’t continue to nurture curiosity-driven science, will we have the capacity to meet the threats of the future—say in twenty or thirty years? If we lose our scientific leadership, we weaken our true national security. It is that simple.

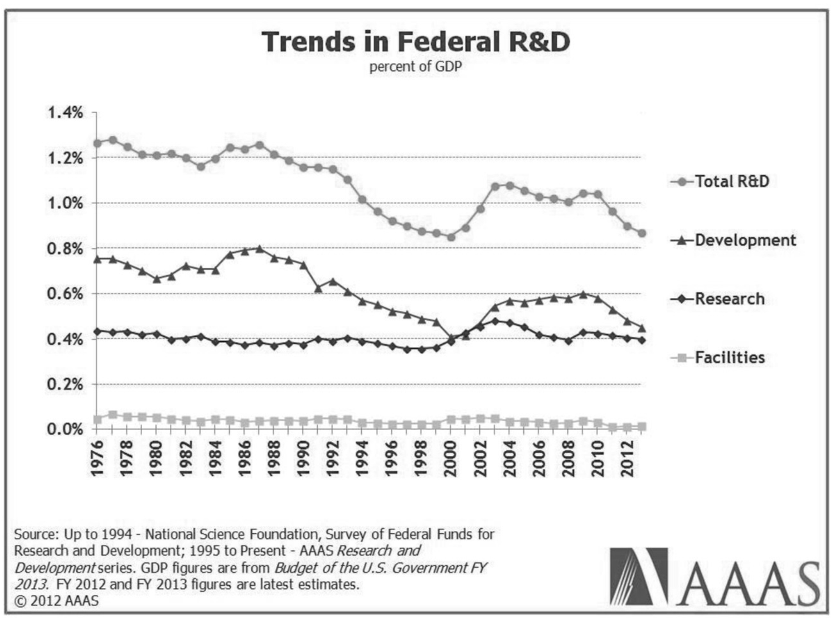
Even if faced with tough budgets, science cannot stand still. By its very nature it is new and ever changing, and requires consistent and continuous forward movement. “No new starts” means not doing science. It means losing the U.S.’s role as a light and leader for the world. It means not attracting and educating the next generation of scientists. It means not being ready for future challenges. Science is the act of discovery. It is not science if it sits still.

Conclusion

With the current fixation on short time lines and near horizons, I doubt that my team's Nobel Prize winning research would be funded today. How many young scientists with Nobel Prize quality ideas and ambitions are not being funded today in the United States? How many are now doing or will do their research in other countries, winning for them the gold of the Prize, but also the economic potential of their discoveries? America set the bar high in its support of science and technology development. Other countries, admirably, are ramping up their innovation engines and in many ways are attempting to emulate our successes. Although we should applaud these efforts, we cannot afford to be complacent and let other countries pass us by. We must stay in the race and compete. Regardless of when and where the mystery of "dark energy" is uncovered it will be a tremendous accomplishment for the world. Yet, from my perspective, as a United States scientist and teacher, I hope that we make these advances here, at home and thereby contribute to humanity's progress.

In closing, the U.S. innovation ecosystem is one of our most precious assets—indeed, one of the world's most precious assets. The Federal Government has a fundamental responsibility to keep this ecosystem healthy because it gives the Nation a powerful competitive edge, providing solutions to major national challenges and fueling economic growth, and because it continues to make the world a better place. Universities and laboratories have a responsibility to conduct first-rate research on key scientific and technological problems with intellectual rigor and efficient use of resources. Working together, we strive to transfer the results of this research to markets and people around the world for the benefit of society as a whole.

Thank you for the opportunity to testify at this important hearing. I am happy to answer any questions that you may have.



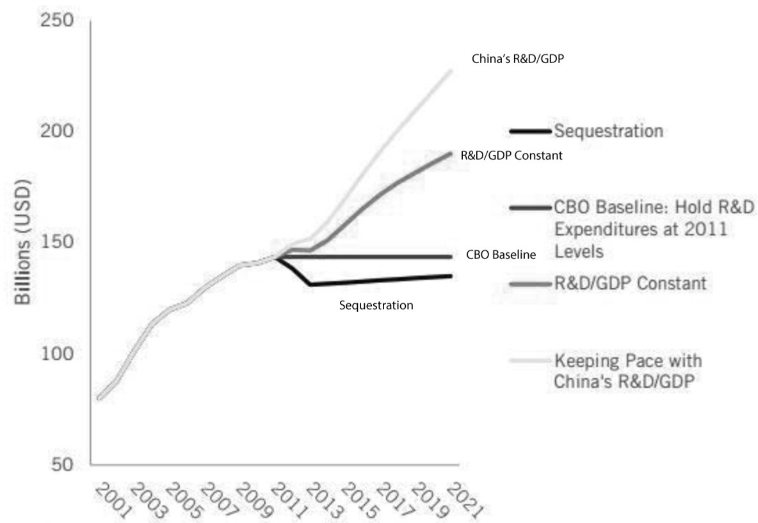
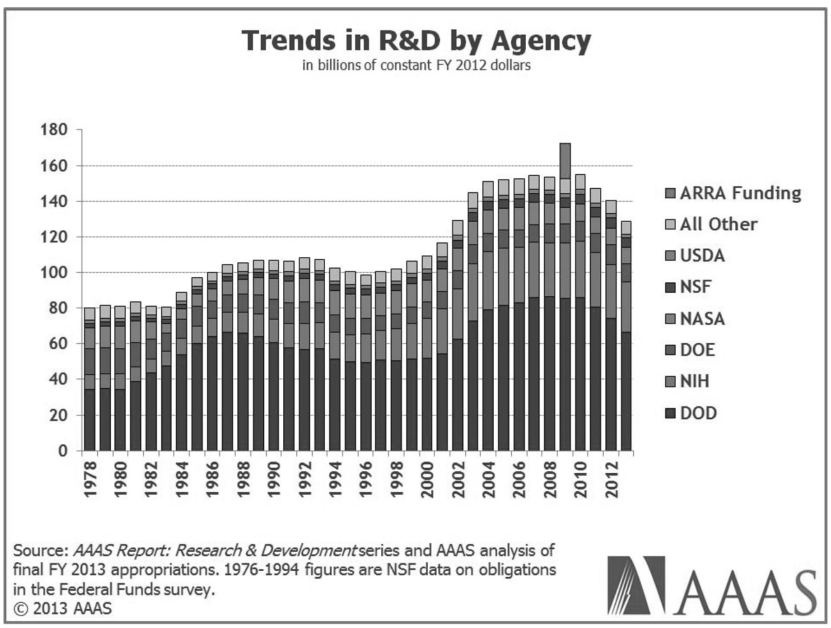
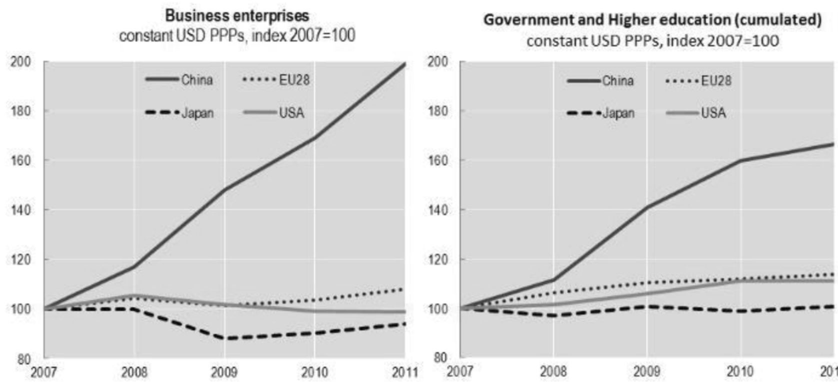


Figure 4: Sequestration and the Three Federal R&D Expenditure Benchmarks, Sources: NSF, OMB, CBO, BEA, ITIF



OECD R&D Intensity Indicators



The latest OECD estimates on Gross Expenditures on R&D (GERD) confirm that the modest recovery initiated in 2010 continued into 2011.

For the whole OECD area, total R&D expenditures grew in real terms by 1.3 percent in 2010, mainly driven by the higher education and government sectors, while business R&D only increased by 0.6 percent.

OECD estimates indicate an overall real growth rate for GERD of 2.1 percent in 2011 driven by a gradual recovery in business R&D (2.8 percent) and sustained growth in research in the higher education sector (2.5 percent), despite a reduction in government R&D (–1.2 percent).

In the EU area, total GERD grew by 3.2 percent in 2011, driven by the business sector (4.2 percent), mainly Germany's (6.4 percent). In contrast, U.S. R&D fell by 0.5 percent in real terms, with growth in higher education offset by lower government and business R&D. After a 2.5 percent drop in 2010, U.S. business R&D (BERD) declined by a further 0.4 percent in 2011.

GERD in China continued to growth at a rapid pace (14.1 percent), mainly driven by business R&D which in 2011 reached more than half the level of U.S. BERD, and 81 percent of EU BERD.

Main Science and Technology Indicators (MSTI) 2013/1

Last update: 16 July 2013

Direct link to the MSTI dataset in OECD.stat
Short address for this page: *www.oecd.org/sti/msti*

The CHAIRMAN. Thank you, sir, very, very much.

Dr. Maria Klawe.

Dr. KLAWE. Klawe. Well done.

[Laughter.]

The CHAIRMAN. Well, I had a little phonetic help here.

[Laughter.]

Dr. KLAWE. Thank you, gentlemen.

The CHAIRMAN. You know what, I have to say who you are.

Dr. KLAWE. Oh.

[Laughter.]

The CHAIRMAN. Not only are you the President of Harvey Mudd College, in fact, you are the first woman to lead the college in its almost 60 years of history.

So we welcome you.

[Laughter.]

STATEMENT OF DR. MARIA M. KLAWE, PRESIDENT, HARVEY MUDD COLLEGE

Dr. KLAWE. Thank you very much.

Chairman Rockefeller, Ranking Member Senator Thune——

How about now?

The CHAIRMAN. Yes.

Dr. KLAWE. All right. I'm off to a great start.

[Laughter.]

Dr. KLAWE. Chairman Rockefeller, Ranking Member Senator Thune, distinguished members of the Committee, it's really a pleasure to be here.

I'll just mention that in addition to being the President of Harvey Mudd College, I'm also on the boards of a couple of technology companies, Microsoft and Broadcom. I'm a computer scientist, and so I'm going to bring a slightly different perspective than our first two witnesses.

I'm the designated hitter for talking about STEM education, and in particular for talking about my particular passion, which is making all STEM disciplines nurturing and supportive to everyone independent of gender or race or whether they're football players or poets or lesbian, gay, or anything else.

And one of the things that Harvey Mudd College does, as a tiny undergraduate institution, is try to be a lab for innovation in STEM education. Not just at the undergraduate level, which is what we are, but also in terms of innovating in partnership with middle school and high schools.

I'm going to focus on talking about computer science because I think it's a particularly important discipline for a number of reasons. The first reason is that in terms of the economic demand, the U.S. economy needs more computer science grads than anything else. The second reason is that computer science is the only discipline in science and engineering where participation by women has declined over the last three decades instead of increased.

Right now about 13 percent of the graduates receiving bachelor's degrees in computer science are female; 4.5 percent are African-American; and 6.3 percent are Hispanic. So computer science has one of the worst diversity records.

It's also important because computer science affects every possible part of our society. It affects health care. It affects education, entertainment, and every area of industry. And so if we don't figure out how to get a larger part of our population to actually participate in this field, we will not be in great shape. But the other reason I want to talk about it is, this is actually not rocket science. It's not even physics. The death of computer science majors is easy to fix.

I'm going to use the rest of my time to tell you how Harvey Mudd College changed our percentage of students majoring in computer science from 10 percent female to 40 percent in 4 years, and how we've kept it there. We have between 35 and 45 percent any given year. And we also have great participation from our African-American and our Hispanic students as well.

I will also talk about how NSF funding helped make that happen and not only helped make it happen at Mudd, but is helping us disseminate our approaches not only to other colleges and universities, which is happening, but also to high schools and middle schools.

So why don't women and African-Americans and Hispanic students want to major in computer science? Number one, they think it's boring. Number two, they think that the kinds of people who do it aren't cool. That computer scientists are guys with no social skills that they wouldn't want to hang out with. And number three, they think they wouldn't be good at computer science.

Harvey Mudd College fixed the gender imbalance by fixing those three things. First of all, we changed our intro CS class to make it the most fun and least intimidating course ever while keeping the rigor. The class has been so successful that now more than half of the students in it are from the other Claremont colleges. And if you don't know about the Claremont colleges I will tell you that Harvey Mudd College is known to have the toughest courses among all the colleges, so usually Pomona and Claremont McKenna and Scripps students and Pitzer students don't take our courses. They love this intro course so much that they take it.

We provided our female CS students with undergraduate research experiences, funded largely by NSF. We know that for both female students and underrepresented minority students, early access to research experiences helps keep students in the system. Finally, we took students to the Grace Hopper Celebration of Women in Computing. NSF funds a certain number of scholarships for undergraduates and graduate students to attend that conference every year. The conference is an amazing experience. Imagine 4,800 participants, of which perhaps a hundred are male, celebrating computer science and careers in computing. It's inspirational to young people.

NSF is supporting our dissemination of these approaches to colleges, to middle school teachers, to high school teachers who are developing curriculum. We thank NSF and we thank you for the support of this committee in making this possible. We are changing the world. And with you, we can change it even faster.

Thank you.

[The prepared statement of Dr. Klawe follows:]

PREPARED STATEMENT OF DR. MARIA M. KLAWE, PRESIDENT, HARVEY MUDD COLLEGE

Chairman Rockefeller, Ranking Member Thune and members of the Committee, my name is Maria Klawe, and I am the President of Harvey Mudd College in Claremont, California. Harvey Mudd is a small, undergraduate-only college of 800 high achieving students. It is a premier science, engineering and mathematics college that prepares the Nation's brightest students to become ethical problem solvers who develop a clear understanding of the impact their work has on society.

Thank you for inviting me to testify before you today on the subject of Federal support of basic scientific research and the societal benefits of such research. I will describe some of the challenges in STEM education today and solutions currently underway to address these challenges. Additionally, I will address the role that government funding and private funding play in supporting these solutions.

Challenges

America's first challenge is K–12 math and science education. We do not have the level of math and science teaching that we need in grades K–12 to ensure there are enough students who are interested in STEM *and* capable of doing well in these subjects once they get to college. We need more engaging and rigorous curricula, teachers who have a strong background in their respective subject areas and more resources for STEM teachers on effective practices.

The second challenge is that the few students who do go on to study STEM in college often choose to major in fields that are not well aligned with where job opportunities exist. Higher education in the U.S. produces more graduates in the life sciences (biology and chemistry) than the economy can employ. These two disciplines, and particularly biology—the most popular science major—tend to include limited study of mathematics, computer science and physics.

So when we think about issues in STEM and where we need additional investment, we should focus on the disciplines where the number of graduates is much smaller than the job opportunities; where the economy needs more people—not just on which academic disciplines students today are interested in studying.

The demand from industry today, in terms of the need for STEM graduates, is for software engineers. Even hardware companies like Intel, Broadcom and Qualcomm that have relied primarily on hardware engineers are shifting to hiring more software engineers. Until recently, they have hired one-third software engineers and two-thirds hardware engineers. They predict that these ratios will be reversed within five years.

Here we have a clear disparity between the needs of industry and the number of computer science graduates we produce. We simply do not have enough students graduating high school with an interest in pursuing computer science. This is in large part due to the striking lack of women and students of color who choose to go into computer science. Nationwide, only 13 percent of computer science majors are female; 6.3 percent are Hispanic and 4.5 percent are black or African American (Computing Research Association, 2012 Taulbee Survey, *www.cra.org/resources/taulbee*). We cannot meet the needs of industry if we are drawing from less than half the population. We also cannot develop the best, most creative solutions when teams are homogenous. Diverse teams with different perspectives create the best solutions.

Research shows that young women especially are reluctant to study computer science for three reasons: (1) Young women think computer science is boring; (2) Young women think that computer scientists are nerdy people with poor social skills; and (3) Young women think they won't be good at computer science. There are also a large number of white and Asian males who don't pursue computer science because of our Nation's negative stereotype of computer scientists.

Solutions

There are many bright, dedicated people working on STEM reform in both K–12 and higher education, and I'd like to briefly describe some of the more successful efforts that are supported with both government and private funding and that deserve to be shared widely.

Redesigned Introductory Computer Science Class Attracts Diverse Students

Harvey Mudd College and other leading institutions have intentionally addressed the lack of interest in computer science by redesigning the introductory computer science course to make it much more compelling and enjoyable for a broad swath of people, including students of color and women, in particular.

To spark interest, Harvey Mudd's computer science faculty changed its CS 5 course from a Java programming class into one that introduces students to a broader range of topics in computer science. We made the class all about finding creative solutions to fun problems in science and engineering using computational approaches. The course uses the Python language, which is easier to apply to Web development and problem solving. CS 5 is now our most popular first-semester course.

To increase women's confidence, we separated the course into two sections, Gold and Black (our school colors), where Gold is for students with no prior computer science experience. This grouping has resulted in a confidence-boosting atmosphere, especially for beginners, who are disproportionately women and students of color. Students who are experienced programmers don't discourage less-experienced, but equally talented, classmates.

This effort began in 2006, and within four years the percentage of female computer science majors at Harvey Mudd jumped from 10 percent to 40 percent, the highest of any co-ed college we know. We now average between 40 to 45 percent.

A National Science Foundation grant (CPATH–2) for $800,000 allowed us to disseminate our highly successful CS 5 curriculum and share our approaches with other institutions, many of which are now teaching the course in its entirety or adapting it with great results.

To increase our female students' sense of belonging in the technology field, we also take a large cohort of first-year female students to the Grace Hopper Celebration of Women in Computing. Students are able to see the variety of jobs available within the discipline and meet successful role models at all career stages, as well as experience an effervescent and welcoming culture. The conference has proved to be a powerful tool in encouraging young women to take more computer science classes and ultimately major in computer science.

Undergraduate Research Opportunities

Several studies have shown that early research experiences for undergraduate women and other underrepresented students increase retention in STEM fields and the likelihood they will attend graduate school. NSF funding has helped Harvey Mudd to increase the number of undergraduate research opportunities available to students, beginning in the summer after their first year. These research projects allow first-years to apply their knowledge, boost their confidence and deepen their interest in the discipline. Female students in particular embrace the opportunity to engage in 10 weeks of intensive, challenging summer research on projects such as artificial intelligence, robotics and educational video games. The experience has helped them discover they are not only able to do the work of a computer scientist but also enjoy it.

Innovative Engineering Education

In engineering education, NSF funding has supported the development of more experiential, project-based learning, proven to be effective in improving learning outcomes.

At Harvey Mudd, we have found that project-based learning, especially early on, also supports retention and diversity in the engineering program. We incorporate design instruction and experiential learning into our students' very first engineering courses. Our engineering design problems require students to work in small teams in order to apply techniques for solving design problems. The team setting builds confidence and allows for a diversity of talent to emerge. Once we get students into the upper courses—the traditional, theoretically based courses—they handle the theory better. We have found that the earlier we expose students to project-based learning, the clearer their learning experience is. Now they see complicated theoretical topics in a way our students, now alumni, couldn't see them even 10 years ago. There is a real slingshot effect; students come out of their first three to four semesters quite advanced. They are not afraid of the technology. They are not afraid of building and testing—having it break and doing it again.

This approach to engineering education has raised retention rates and increased the number of women in the major. In the past 10 years, we've gone from 30 percent female engineering majors in the Class of 2003 to 42 percent female majors in the Class of 2013. We are on track this year to have our first female majority of engineering majors in a graduating class; of engineering majors in the Class of 2014, 56 percent are female.

NSF funding has supported the sharing of our educational models through its support of the Mudd Design Workshops, a biennial program that brings together engineering educators, practitioners and researchers to discuss issues of innovation in design and engineering education. Engineering faculty share effective educational practices about the inclusion of design courses and elements into other institutions' engineering curricula.

NSF Grant for the Flipped Classroom Study

Government funding supports research into STEM teaching and learning and the development of new, more effective learning technologies. For example, flipped classrooms are being implemented nationwide, much like the concept of massive open online courses (MOOCs). In a flipped or inverted classroom, lectures are delivered outside of class—via online videos or screencasts—and viewed by students during their free time. Classroom time is then used for instructor-mediated, hands-on learning. Many think that the flipped format has the potential to transform STEM education by increasing student time spent on what research has proven to be the most effective teaching techniques without sacrificing material coverage or educational scaffolding.

Educators are beginning to invert their classrooms, but there is limited data on learning gains from controlled studies. Four Harvey Mudd College professors have been awarded a three-year, $199,544 NSF grant to rigorously examine the impact of inverting three STEM courses—in chemistry, engineering and mathematics—by measuring student learning gains. Several STEM fields were included in the study so that results could be applicable across fields and institutions.

K–12 Outreach

Our nation's economic future depends upon improving the K–12 pipeline into the STEM fields. We must expand the talent pool of interested and qualified students capable of pursuing STEM careers, crucial for U.S. economic competitiveness and growth, as well as for developing solutions to the pressing challenges–energy, climate, healthcare, security–facing our world. Yet many students never make it into the STEM pipeline, because of inadequate preparation in math and science in their K–12 systems.

Federal research and development funding as well as private funding are playing a vital role in college outreach programs that seek to strengthen K–12 STEM education. NSF funding allows colleges and universities to share their expertise and develop new learning technologies to improve the quality of STEM teaching and learning in K–12 classrooms across the country. These programs depend on government funding to support their efforts to transform K–12 STEM instruction.

MyCS—Bringing Computer Science to Middle Schools and High Schools

The NSF funds an innovative computer science outreach program for middle schools and high schools that do not have the resources to offer such courses. Computer scientists at Harvey Mudd have developed a model program, funded by a $596,501 NSF grant, called "MyCS: Middle Years Computer Science." The goal is to develop positive computational identities among middle-school students: encouraging their self-efficacy, enjoyment and future engagement in computer science. MyCS is designed to pique the interest of early adolescent students, especially from groups underrepresented in computer science, and build a foundation of computer science vocabulary, algorithmic thinking and skills. The MyCS program works with several schools with predominately Latino-Latina and Pacific Islander populations. The classes expose these students to computer science while they are in the pivotal years of identity formation and excite them about computational creativity before they have been convinced that CS is something "people like me" don't do.

The program includes professional development workshops for teachers—to provide the foundation for teaching MyCS—and academic-year support for MyCS students and teachers, provided by Harvey Mudd students and faculty. It also includes assessments to record changes in students' and teachers' computational self-efficacy and the influence of MyCS on their future computational choices. The benefits: these communities will continue to develop computationally confident students even after the project concludes. Second, assessments will cull less effective variations and facets of MyCS, providing a ready-to-go curriculum that will succeed in further regional deployment and will be prepared for larger-scale vetting, national trials and broader adaptations.

What 10K Novice Teachers Can Learn from Teachers with 10K Hours of Experience

High school computer science teachers, especially beginners, face significant challenges in making the subject comprehensible for their young audiences. A broad NSF-sponsored computer science initiative seeks to create 10,000 new, well-qualified computer science teachers in 10,000 high schools by 2017. As part of that initiative, Harvey Mudd CS professor Colleen Lewis recently received a three-year, $598,513 NSF grant to develop a library of online resources that will help beginning and developing high school computer science instructors teach 90 basic computer science concepts. Lewis' project will allow teachers to go online, find the concept they are struggling with and identify five to 10 effective strategies. Her project, "What 10K Novice Teachers Can Learn from Teachers with 10K Hours of Experience," seeks to develop better and additional computer science teachers, improve the overall quality of computer science instruction and increase access to computer science for students of color and those who are economically disadvantaged.

The Games Network: Games for Students, Games by Students

An NSF grant has expanded a K–12 outreach program in which Harvey Mudd computer science students work with middle-school social studies teachers to develop educational video games. The program's goal is to shatter stereotypes about the computer science field by introducing younger students to the fun, creative side of software development. Sixth- and seventh-grade students test the games and provide feedback to the college-level students, who gain the opportunity to create games for an audience other than themselves. The grant also funds the creation of a guidebook to help other schools start similar projects.

Private Funding

While federally-funded programs play a vital role in improving K–12 STEM education, it will take multiple efforts and partnerships to implement better STEM learning opportunities for all of the Nation's K–12 students. Private funding, both in conjunction with Federal funding and on its own, plays an essential role in supporting flexible programs that strengthen K–12 STEM education and increase students' ability to succeed in STEM careers.

Math for America

Math for America, of which I am a board member, is a nonprofit organization that seeks to significantly improve math education in public schools by providing professional development and support for outstanding math and science teachers at the high school and middle school levels. For example, the Math for America Teaching Fellows Program recruits participants with a strong math background, who receive funding to complete a master's degree in education. Fellows commit to teaching math in public schools for at least four years and to participating in professional development and coaching programs. In exchange they receive an annual stipend of up to $20,000. Math for America was founded in New York by mathematician and philanthropist James Simons. Its expansion to other cities including Los Angeles, Boston, Salt Lake City, San Diego and Washington, D.C. is supported by matching funding from the NSF, which has been critical in extending its reach across the Nation.

Homework Hotline

James Simons also supports Harvey Mudd College's Homework Hotline, an over-the-phone, mathematics and science tutoring service for students in grades 4–12. Launched in February 2010, the hotline was modeled after the successful Homework Hotline created at Rose-Hulman Institute of Technology in 1991. Harvey Mudd partnered with RHIT to bring the program to the College's local communities. RHIT and Harvey Mudd share a common mission to enhance academic performance, reinforce classroom concepts and promote interest in mathematics and science. RHIT shared its system with us, provided technical advice for its implementation and continues to be a valued collaborator. Harvey Mudd College Homework Hotline tutors helped 2,478 students last fall, a 21 percent increase from the previous year in the number of 4th- through 12th-graders successfully coached in STEM subjects through the free hotline.

Physics and Computer Science MOOCs for High Schools

Many high schools, especially those serving populations underrepresented in STEM, are not able to offer AP physics or computer science classes because they lack resources or teachers trained in these subjects. With the help of the Bill and Melinda Gates Foundation, Harvey Mudd is developing two MOOCs (Massive Open Online Courses) for high school teachers who would like to teach AP physics or computer science but who don't have the expertise. These two MOOCs will provide teachers, who already have the pedagogy training, with lectures, hands-on activities, and problem sets in computer science or AP physics. The MOOCs will draw on the best educational practices and proven strategies for learning these two topics. A team of faculty, students and an alumna of Harvey Mudd is creating the MOOCs and is set to deploy them this fall, first in local high schools and then regionally and nationally.

Community Outreach Programs: Science Bus, Pathways

Harvey Mudd recently received a $150,000 grant from the Ralph M. Parsons Foundation to support community engagement, including outreach to K–12. The funding helps support programs such as Science Bus, a student-run outreach effort at Harvey Mudd based on a model developed at Stanford University. Science Bus coordinates student volunteers to visit local elementary schools and teach hands-on science lessons. Lessons include a science demonstration, an experiment and a discussion, with an overarching focus to build positive associations with science. The program's goal is to inspire more young women and men, especially from groups that are currently underrepresented, to pursue higher education and careers in science.

Another such effort is Pathways, a Los Angeles-area mathematics outreach program based in the Department of Mathematics at Harvey Mudd. Professional mathematicians eager to share their love of mathematics with elementary, junior high and high school students visit LA-area schools whose populations are often predominantly underrepresented in STEM. The volunteers give 40–50 minute presentations designed to expose students to parts of mathematics that are often unseen outside of college, but that are nonetheless accessible and often incredibly eye-opening. Similar outreach programs exist at many colleges and universities; they can play an important role in sparking interest in STEM and deserve greater support.

Conclusion

Our primary challenge in STEM education today is to make K–12 science, math and technology classes engaging and rigorous so that more students are both interested in and capable of pursuing degrees in STEM. We must also attract more undergraduate students—particularly women and students of color—to major in fields that are in demand in industry; thus spurring the economic growth and technological innovation upon which our country's economic success depends. Federal research and development funding, as well as private funding, are vital to our current and future efforts to strengthen the K–12 pipeline, increase the diversity of the STEM talent pool, and ultimately improve our Nation's capacity to tackle the challenges of an increasingly technological world.

The CHAIRMAN. Well, thank you very much.

I don't understand why computer science is not cool. I disagree with the premise.

Dr. KLAWE. No, no, no. It's not that it's not cool; it's very cool. It's the coolest field there is. The problem is that our young people, and young women in particular, don't think it's cool.

The CHAIRMAN. I know, but I—why?

Dr. KLAWE. Because of the image of the——

The CHAIRMAN. They think they can't——

Dr. KLAWE.—people who do it.

The CHAIRMAN.—do it. They think they can't do it.

Dr. KLAWE. They think they can't do it, but they also think it's for guys. They think it's a boy thing.

The CHAIRMAN. Wow.

Dr. KLAWE. There is tons of research on it, including done by myself.

The CHAIRMAN. Maria and Amy, will you—are you willing to change that?

Senator CANTWELL. I'm well aware, and we'll have questions when we get to that. Thank you.

Senator KLOBUCHAR. Being that we're in computer states alike.

The CHAIRMAN. All right. Well, that's both inspiring and depressing.

[Laughter.]

Dr. KLAWE. It's not often that you get a twofer.

[Laughter.]

The CHAIRMAN. No, but I mean generally speaking, in my office, I mean, I think that if women ran the world, we'd be a lot better world.

Dr. KLAWE. Of course.

[Laughter.]

The CHAIRMAN. So women should be able to understand that computer science is OK.

Dr. KLAWE. And at Harvey Mudd they do.

The CHAIRMAN. OK. There we go.

And finally, Dr. Stephen Tang, President and CEO of the University City Science Center in Philadelphia.

STATEMENT OF STEPHEN S. TANG, PH.D., MBA, PRESIDENT AND CEO, UNIVERSITY CITY SCIENCE CENTER, PHILADELPHIA, PENNSYLVANIA

Dr. TANG. Thank you, Chairman Rockefeller and Ranking Member Thune.

And good afternoon, everyone.

I am Steve Tang. I'm the President and CEO of the University City Science Center in Philadelphia. And I'm honored to join my distinguished colleagues on today's panel.

I'd like to start by confirming that the Science Center supports the reauthorization of the America COMPETES Act. Since 2007, America COMPETES has provided critical investments in science, space, energy, STEM education, and innovation, all with the goal of increasing our Nation's global competitiveness. The Science Center also supports the Act's establishment of a regional innovation program to encourage regional innovation strategies for technology commercialization and tech-based economic development.

And toward the end of my remarks, I'd like to share with you a few new ideas on how Congress can help encourage still more technology transfer that will ultimately lead to new companies, new jobs, and new economic growth.

With a PhD in Chemical Engineering from Lehigh University, an MBA from the Wharton School, and a bachelor's degree from the College of William and Mary, I admit to being one of those socially inept males——

[Laughter.]

Dr. TANG. That Dr. Klawe was speaking about. But I also have an extensive background in science, business, and entrepreneurship. I have a firsthand understanding of the power and potential of technology commercialization, too. I also served as a member of the U.S. Department of Commerce's Innovation Advisory Board, which guided the 2012 study of the Nation's economic competitiveness in innovation capacity pursuant to the last reauthorization of America COMPETES.

This report made several thoughtful recommendations, and the President has since issued a number of Executive Orders that have drawn attention to this subject; however, I believe that additional legislative action is needed to translate these ideas into concrete results.

At the Science Center we cultivate and expand the possibilities that open up when research moves out of the lab and into the marketplace. We are the Nation's oldest and largest urban research park. And I'm proud to report that we are celebrating our 50th anniversary. As an independent nonprofit organization, we are a dynamic hub for innovation and entrepreneurship in Pennsylvania, New Jersey, and Delaware. We provide space, services, and support to academics and entrepreneurs working in diverse emerging technologies such as materials, information technology, life sciences, and clean tech.

Over the past 50 years graduates from our incubators have created more than 15,000 direct jobs that remain in Greater Philadelphia today and contribute more than $9 billion to the region's economy annually.

Our current startups are pursuing technological breakthroughs in fields such as food safety and cancer treatment. Many of these companies rely on targeted Federal funding from NSF and other agencies covered under America COMPETES. For example, one of our current residents, Graphene Frontiers, a spinout from the University of Pennsylvania, is developing a large-scale production process for graphene, a nano-material with an unbeatable combination of strength, flexibility, and conductivity that promises to revolutionize everything from scientific instruments to consumer electronics.

Graphene Frontiers has received nearly a million dollars from NSF funds. We're also collaborating with the Children's Hospital of

Philadelphia on the commercialization of an online interactive health, wellness, and prevention system. This project is funded in part by a million dollar grant from NSF's Accelerating Innovation Research program.

At the Science Center we support technology commercialization in the broadest sense by acting as an innovation intermediary, or linchpin, if you will, that brings together academia, industry, and capital. Our QED Proof of Concept Program provides business support for academics working on life-science technologies with high commercial potential. The goal is to retire the business risk in these early stage projects so that they can attract follow-on investment. Twenty-two colleges, universities, hospitals, and research institutions throughout the Greater Philadelphia area participate in QED.

Of the 12 research projects that have completed the program, five have resulted in new licenses or companies based on those technologies. And what's more, these five projects have also attracted more than $9 billion in follow-on funding from the private sector.

In our new Phase 1 Ventures Program, we'll help early stage companies apply for and obtain SBIR and STTR grants and then provide the companies with management support and access to outside expertise, as well as connections to private sector funding in order to help them grow.

The Science Center's vast network of relationships and connections helps make us a leader in technology-based economic development, or TBED. Yet like other research parks and other nonprofit TBED organizations, we are unable to fulfill our potential as catalysts for tech transfer and commercialization simply because we're not eligible to apply for most grants from NSF or other Federal agencies. This lack of eligibility is due to the fact that we're not an academic institution. As a rule, access to most grant opportunities from NSF and other agencies are limited to degree-granting academic institutions.

I certainly fully appreciate the current budget situation and understand that in many ways we're playing a zero-sum game. However, I believe there are more effective ways we can allocate and deploy existing research dollars to maximize the Nation's return on investment.

So I appear before you today to advocate not only for the reauthorization of COMPETES, but for two other proposals. First, the Science Center supports an increase in allocation of existing Federal funding for translational research, commercialization, and tech transfer by universities and companies alike as a critical and logical compliment to the Nation's historic emphasis on basic research. And second, we support an expansion of the ability of TBED organizations like the Science Center, which are not degree-granting academic institutions, to apply for and secure Federal grants from NSF and other agencies.

These moves would enable organizations like ours to ultimately help speed the acceleration of cutting-edge technologies from lab to the market. In addition, the Science Center supports measures such as H.R. 2981, the TRANSFER Act of 2013, which would allocate existing funds to proof-of-concept activities that validate the commercial potential of early stage research.

This legislation would require that agencies such as NIH, NSF, DOD, and DOE devote a small portion of the already-scheduled increase in their STTR funding to earlier stage proof-of-concept and prototype development research. This reallocation of funding would further incentivize the commercialization of new technologies and the creation of small businesses.

I thank you very much for your time, your attention, and your interest in this important topic. And I welcome your comments and questions.

[The prepared statement of Dr. Tang follows:]

PREPARED STATEMENT OF STEPHEN S. TANG, PH.D., MBA, PRESIDENT AND CEO, UNIVERSITY CITY SCIENCE CENTER, PHILADELPHIA, PENNSYLVANIA

Thank you, Chairman Rockefeller and Ranking Member Thune. And good afternoon, everyone.

I'm Steve Tang, President and CEO of the University City Science Center in Philadelphia. It's an honor to join my distinguished colleagues on today's panel.

I'd like to start by confirming that the Science Center supports the reauthorization of the America COMPETES Act. Since 2007, America COMPETES has provided critical investments in science, space, energy, STEM education, and innovation, all with the goal of increasing our Nation's global competitiveness.

The Science Center also supports the Act's establishment of a "Regional Innovation Program" to encourage regional innovation strategies for technology commercialization and tech-based economic development.

And toward the end of my remarks, I'd like to share with you a few new ideas on how Congress can help encourage still more technology transfer that will ultimately lead to new companies, new jobs and new economic growth.

With a PhD in chemical engineering from Lehigh and an MBA from Wharton, and with an extensive background in science, business and entrepreneurship, I have a first-hand understanding of the power and potential of technology commercialization.

I also served as a member of the U.S. Commerce Department's Innovation Advisory Board, which guided the 2012 study of the Nation's economic competitiveness and innovation capacity, pursuant to the last reauthorization of America COMPETES. This report made several thoughtful recommendations, and the President has since issued a number of Executive Orders that have drawn attention to this subject. However, I believe that additional legislative action is needed to translate these ideas into concrete results.

At the Science Center, we cultivate and expand the possibilities that open up when research moves out of the lab and into the marketplace. We are the Nation's oldest and largest urban research park, and I am proud to report that we are celebrating our 50th anniversary.

As an independent nonprofit organization, we are a dynamic hub for innovation and entrepreneurship in Pennsylvania, New Jersey and Delaware. We provide space, services and support to academics and entrepreneurs working in diverse emerging technologies, such as materials, IT, life sciences and clean tech.

Over the past 50 years, graduates of our incubators have created more than 15,000 direct jobs that remain in Greater Philadelphia today and contribute more than $9 billion to the regional economy annually.

Our current start-ups are pursuing technological breakthroughs in fields such as food safety and cancer treatment. Many of these companies rely on targeted Federal funding from NSF and other agencies covered under America COMPETES.

For example, one of our current residents, Graphene Frontiers, a spinout from the University of Pennsylvania, is developing a large-scale production process for graphene, a nanomaterial with an unbeatable combination of strength, flexibility and conductivity that promises to revolutionize everything from scientific instruments to consumer electronics. Graphene Frontiers has received nearly $1 million in NSF grants.

We're also collaborating with the Children's Hospital of Philadelphia on the commercialization of an online interactive health, wellness and prevention system. This project is funded in part by a $1 million grant from NSF's Accelerating Innovation Research program.

At the Science Center, we support technology commercialization in the broadest sense, by acting as an innovation intermediary—or linchpin—that brings together academia, industry and capital.

Our QED Proof-of-Concept Program provides business support for academics working on life science technologies with high commercial potential. The goal is to retire the business risk in these early-stage projects, so that they can attract follow-on investment.

Twenty two colleges, universities, hospitals and research institutions throughout Greater Philadelphia participate in QED. Of the 12 research projects that have completed the program, five have resulted in new licenses or new companies based on their technologies. What's more, these five projects have so far attracted more than $9 million in follow-on funding from the private sector.

And our new Phase 1 Ventures Program helps early-stage companies apply for and obtain SBIR and STTR grants, and then provides the companies with management support and access to outside expertise, as well as connections to private sector funding, in order to help them grow.

The Science Center's vast networks of relationships and connections help make us a leader in technology-based economic development, or TBED.

Yet, like other research parks and other non-profit TBED organizations, we are unable to fulfill our potential as catalysts for tech transfer and commercialization, simply because we are not eligible to apply for most grants from NSF and other Federal agencies. This lack of eligibility is due to the fact that we are not an academic institution. As a rule, access to most grant opportunities at NSF and other agencies are limited to degree-granting academic institutions.

I fully appreciate the current budget situation, and understand that we're playing a zero-sum game. However, I believe there are more effective ways we can allocate and deploy existing research dollars, to maximize the Nation's return on investment.

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Thank you for your time, your attention, and your interest in this important topic! I welcome your comments and questions.

The CHAIRMAN. Thank you very much, sir.

I'm going to start out, maybe this is a little bit controversial, but it isn't to me, I think we have to face up to it in the Congress and as a nation; and that is the whole question of sequestration. Well before sequestration, The Science Coalition published this: Sparking Economic Growth, and it highlights companies created from federally-funded university research fueling American innovation and economic growth.

We have copies for anybody who wants to have that. It is sort of a follow-up to a previous report and includes this quote: "a daunting outlook for America if it were to continue on the perilous path it has been following in recent decades with regards to sustained competitiveness."

Sequestration has just made things worse. It sort of got in by accident. Yes, we voted it in, but it was not meant to stick around. I think on both sides of the aisle there's quite a lot of frustration with it particularly as it affects one's own university research and other types of things and in general. I mean, you know, in West Virginia food stamps are important and a lot of people will be getting far fewer food stamps. There are so many dimensions to it. It affects all aspects of our life.

The Vice Chancellor for research at the University of Kansas referred to sequestration as a slowly growing cancer that threatens young scientists' careers.

And I think, Dr. Klawe, that people dream and are inspired toward careers not always by literal things, but sort of by a sense of open space, open possibilities. Sequestration is something that closes that sense of open possibilities.

The University of Maryland's chief research officer said that he's witnessing a brain-drain with top researchers looking to move abroad. And it used to be, I believe, that we welcomed budding scientists from overseas, from the Philippines, from Taiwan, from India, from various places, China, et cetera; and they would come and they would stay at our universities. They'd get their degrees, and they would stay. And what they do now is they get their degrees, and then they go home.

I can't criticize that. I can't criticize that because they belong to nations that need them in other ways. On the other hand, I mourn it simply because of what we are losing, and it's not incidental. I think it's due to the lack of resources. They don't see a resource-based platform which gives them reason to hope.

So question for all of you, each of you, do each of you agree with the concerns raised by these comments? That's a little bit direct, but that's the way I'm feeling. How would each of you describe the situation in this country in terms of our ability to train a scientific workforce to innovate and be competitive?

Dr. Droegemeier, just——

Dr. DROEGEMEIER. Thank you, Mr. Chairman.

Yes, indeed, I think you've hit the point very, very well. At NSF and in FY 2013 budget, NSF was able to mitigate some of the damage from sequestration, but that's not going to be possible going forward. And there's great deep concern about the impacts in terms of reducing numbers of grants which will fund our students to become next-generation scientists. It will have a huge impact on facilities, perhaps leading to the nonconstruction of facilities that are planned or maybe even in the shuttering of facilities that already exist.

One thing I'm very concerned about is the participation broadening that is so important that we heard in terms of drawing women and underrepresented individuals in the workforce. Given what the demographics of our Nation will look like 20 or 30 years from now, we simply won't have the people to do the innovation, to do the research to keep us competitive.

And the other thing I think that's quite concerning is the fact that sequestration, then with the government shutdown, as well, on top of already very problematic budgets and very, very tough success rates, low success rates in agencies, in Federal agencies; people are getting discouraged. We're seeing students say, you know, I really don't think I want science as a career.

I look at my faculty mentors. I hear what they're saying. I watch their body language. So not only are we potentially losing the generation we already have, but the next generation coming in, they're quite discouraged.

And as you said earlier, we had a hurdle to overcome when "Rising Above the Gathering Storm" was written. It's not only gotten worse, it's a problem that is not symmetric in its dimension. It—you can reduce the funding very quickly and we can go down the hill very quickly, but climbing back up takes a much, much longer period of time. So it's not easily reversible. You can't just turn it around and get back as quickly as you lost ground to begin with.

The CHAIRMAN. Dr. Perlmutter.

Dr. PERLMUTTER. And I think I can echo that. And I would say that the cumulative effect of having not only sequestration but also a series of continuing resolutions and then of course recently the shutdown has created a rather extra problem for the sciences that you see in the very difficult time that any of the agencies have in making any new starts. So beginning any new programs becomes very, very difficult in an environment where they can't predict where they're going to be in an upcoming—you know, during the year, let alone over several years.

And of course for the sciences, not doing new starts is particularly damaging. If you aren't starting new things in the sciences, you really aren't doing science.

In the examples where I was describing today this work on dark energy, I can see it in both the big and in the small. In—there was a large, a very interesting satellite program that we've been working on, oh, since the year 2000, which had been approved and was, you know, would have gone ahead in any other environment; but it's been kicked down the road over and over again to the point that now Europe is moving forward with their own version of a satellite telescope to explore dark energy.

And in fact, the post doc that I just mentioned was planning to be in Europe, so they would get to do their dark energy work there.

Even smaller projects, projects such as the Dark Energy Spectrographic Instrument (DESI) are being negatively affected. A space project is still something that is very, very viable. It's called W-first. And it's something that we obviously should definitely do before we are beaten at our own project by the Europeans.

On the small-scale projects like the ground-based project called DESI, it's a few tens of millions of dollars, and projects like that can't get going even though they're highly ranked, they're approved, and yet the lack of certainty for the agencies means that they can't actually commit to beginning anything new. And you know, these are just two examples—DESI and WFIRST—that I'm closely aware of because they're in my own immediate field, but talking to the scientists around me, it's the same problem everywhere.

And of course, this just isn't doing science at the level that the United States, you know, is known for.

The CHAIRMAN. Thank you, sir.

Dr. KLAWE. So——

The CHAIRMAN. Doctor.

Dr. KLAWE.—one of the things I'm really excited about that the NSF has been pushing for several years now is broadening participation in computer science so that we do attract young women, African-Americans, Pacific Islanders, Native Americans, Hispanics and other underrepresented groups to computer science.

As I watched what happened at NSF several months ago due to sequestration, I saw a two-week process unfold. Week one, the person who leads this particular program, in CS did a presentation at the White House and was told that wonderful results were coming out of the program and how exciting it was and so forth. Week two, her entire budget was cut—gone.

They've done some juggling, and they've tried to put some of it back; but I mean, it's just so frustrating because I—it's just like doing big science projects, if you're going to try and change the way that we teach computer science, the way that we attract young people to be interested in this field and then all of a sudden all of your, everything grinds to a halt, you just slide backward so quickly.

So I agree with the comments that you read out. Sequestration is not just hurting our research, our basic research, it's hurting innovation, and it's also hurting our efforts to attract more young people into STEM disciplines where they are so deeply needed.

The CHAIRMAN. I thank you.

Dr. Tang.

Dr. TANG. Mr. Chairman, there's no question sequestration has hurt and will continue to hurt the business of science. And I use those words intentionally. All businesses and business decisions always require minimal uncertainty in either revenue or expenses. And sequestration has caused many universities to reconsider their overall commitment, particularly to younger faculty members.

We see this through our 31 shareholders, which are all universities and research institutions in Greater Philadelphia. The economy in Greater Philadelphia is largely driven by higher education and the hundred institutes of higher education there. And it's—so I would say it's a very fragile situation.

And I would refer to Senator Alexander's opening comments about the commitment that as a nation China is making as a percentage of its GDP to the sciences and to innovation.

We cannot afford fits and starts in the funding for research overall. And I think it ultimately disadvantages us.

The CHAIRMAN. Thank you, sir.

Senator Thune.

Senator THUNE. Thank you, Mr. Chairman. And Mr. Chairman, I want you to know that you are living proof that it's possible to be both brainy and cool.

[Laughter.]

Senator THUNE. It can happen.

The CHAIRMAN. I'm his friend.

Senator WARNER. Is that for the record?

Senator THUNE. That's for the record.

Dr. Tang, could you elaborate on the potential for federally funded research to be conducted by consortia that consist of multiple research institutions, with or without industry participation, as opposed to single institutions that may compete with each other for the same Federal funding? What are the potential benefits of a consortium approach, if you are willing?

Dr. TANG. Well, the advantages are numerous, Senator. Thank you for the question.

We see in Greater Philadelphia the ability to connect resources between universities as one of the differentiating factors that the Science Center brings together through its shareholders.

You mentioned with or without industry. I would strongly submit that it has to be with industry. The great inventions that need to come into the marketplace need to be validated by industry. This is one distinct difference in the way we look at applied research and translational research in that it requires market validation, not peer review to elevate good ideas. So there's always better strength when you connect the university resources to industry, and to each other.

What we've found in our own experience is that often even within universities there's not great communication or collaboration, and so we have to be the catalyst that creates that link between them.

We also think that our role as a nonprofit serving the interest of academia in industry is vitally important, as well. So that intermediary role helps catalyze much more innovation than you would have in the absence.

Senator THUNE. How can current research grant programs be structured to encourage and better leverage funding from multiple public and private sources, including state and local governments, corporations and foundations? You talked a little bit about the role that you play in that, but what are the current opportunities and roadblocks for those types of public-private partnerships?

Dr. TANG. Well, the science—thank you.

The Science Center is—was formed 50 years ago as a public-private partnership, and we continue as one today. And we've had great success in aligning the interests of the City, State, and Federal Government in funding our programs because we've been able to show the impact both at a local and a national level. So I think it's a very powerful formula for sustainability of programs. And it perhaps is an alternative to looking at just line items in a budget for single institutions and single—with single causes.

So we're very much in favor of that by all——

Senator THUNE. And what roadblocks to that? I mean, what do you see? What are the things that stand in the way of that happening on a more regular basis?

Dr. TANG. Well, there's the normal, I think, red tape at the City and the State and the Federal level; but I also think that the cultures between academia and industry are quite different. And so you need an organization that can interpret those differences and align them. And that's certainly one of our jobs.

Senator THUNE. I want to direct this, if I might, to Dr. Perlmutter. In this committee we routinely discuss the need for a U.S. global competitiveness in leadership and science. With DOE's Office of Science, with the National Science Foundation, and support from the State of South Dakota; the United States has established a world-leading underground research facility that I mentioned earlier, we referred to it as SURF in the former Homestake Gold Mine.

And my question is, given the worldwide shortage of similar underground research space, can you describe what scientific frontiers could be explored by leveraging the unique opportunity to pull ahead of global competitors in the fields of high energy and nuclear physics?

Dr. PERLMUTTER. It was very—actually, that—yes. It was quite exciting to see just even last week the announcement of the very first of these big steps forward in the SURF underground lab from the LUX experiment. This—for those who aren't following closely, along with this mystery of, what is most of the universe made up of in its energy content, this dark energy; there's also a long-standing mystery of what is most of the, you know, ordinary matter of the universe made of; and that's this dark matter question.

And so now in your state, an experiment at the Sanford Underground Research Facility has pulled ahead of other experiments as the leading technique for studying dark matter. The larger issue is that SURF is an excellent example of the sort of facility that national resources can build for fundamental research that can be used for many, many different experiments and different purposes. And it's very difficult to do it in any other way than with national resources.

Right now my understanding is that it's near that awkward stage of trying to figure out what's going to happen into the future because there isn't this long-term perspective in the agencies and that—and they don't know what their funding profiles are going to be that they can promise that they should be building up the capabilities of SURF.

In principle you should be able to use it to be at the receiving end of the—of an accelerator experiment that starts over at Fermilab in Illinois, which would be a fascinating experiment to see run. It can also be a site to do other very fundamental physics experiments, as well, waiting to see, you know, if protons could decay. There's a whole portfolio of questions that you would have assumed that by now we would already be up and running and building if we were able to move more, you know, aggressively into the future with, you know, with our funding and our understanding of what it was that we want to do for fundamental science.

Senator THUNE. Thank you. And that's some really cool stuff that's going on out there.

My time has expired. Thank you, Mr. Chairman. Thank you.

The CHAIRMAN. We've got a lot of cool stuff going on.

[Laughter.]

Senator THUNE. It's very cool.

The CHAIRMAN. Senator Thune and I both come from highly urban——

[Laughter.]

The CHAIRMAN.—states with multiple universities and subsistence, so we compete a little bit sometimes.

[Laughter.]

The CHAIRMAN. Senator Cantwell.

STATEMENT OF HON. MARIA CANTWELL, U.S. SENATOR FROM WASHINGTON

Senator CANTWELL. Thank you, Mr. Chairman. And thank you for this important hearing and to bringing up these points about sequestration, because as a state that heavily depends on research with the north, you know, the Pacific Northwest Lab in Richland, Washington, and the University of Washington getting so much funding from NIH; we are definitely impacted. And just NIH alone, those jobs of research are about 8,000 jobs in the Puget Sound area, to say nothing about the jobs at the labs.

So I think a few years ago the Chairman of Microsoft, Bill Gates, and the Cummins CEO advocated for a very large increase in ARPA–E as a way to say this is what we were missing as far as the opportunity to continue research there. And I certainly appreciate everything that's been said about STEM today.

And so I guess I have a couple of questions for you, Dr. Klawe, about particularly—well, my understanding is that there's something, and this was a few years ago, a need in the U.S. for something like 300,000 computer scientists, in which we graduate something like 70,000 a year. So we're constantly falling behind, and thereby the immigration issue becomes an active debate.

And so part of it is making up, as you are saying, with the female population. I once asked an Asian engineer why there were so many engineers, women engineers in China. And she said, well, because we have a national saying that women hold up half the sky. And she said, so we know that it's part of our responsibility. Here I'm not sure we have the same incentives. And certainly now today money is part of the issue.

And so I guess two questions I have for you. One, do you think taking some of these resources of America COMPETES and directly increasing the number of slots at our major engineering facilities as a way to catch up to that number that we need on annual basis is a good idea? And then the second idea is, I just keep, as I go through my State, and we've met many people, there's a former NAACP Chairman, Carl Mack, who has an organization that is just SEEK, Summer Experience For Engineering For Kids, that's focused, again, on minority kids. That they're doing great things, getting younger kids more involved.

When I went to high school, I ended up taking Latin and typing. Typing was the requirement. Latin was part of the language requirement. To me the most important language today is computer programming language.

Should we look at incentives at the Federal level to encourage states to make something like C++ or Java as part of a 1-year curriculum requirement for high schools or incent high schools to do that so more and more people are exposed? Just as I was forced to take typing, get people exposed to what really is going to be the language of the 21st century.

Dr. KLAWE. I had to take Home Ec——

Senator CANTWELL. OK.

[Laughter.]

Dr. KLAWE.—which I was really bad at. Any time I get near a sewing machine, it breaks.

Computers on the other hand—so let me start by answering your first question, then I'll get to your second question. The answer is yes in both cases, but let me explain why.

Every institution that I know of is overloaded by the number of students who want to study computer science right now. I'll give you an example at Harvey Mudd. We're a tiny place. We have 800 students in total. We used to graduate roughly 25 to 30 of our roughly 200 majors a year in computer science; now we have 80 of the 200 majors. And we also have a huge overload from the other colleges who all want to take our CS courses.

So just to give you a sense, the number of faculty in our computer science department is ten. The number of faculty in our engineering department, which used to graduate 80 or 90 majors, is 19. I cannot, as President, take an engineer over here and say, hi, wouldn't you like to be a computer science faculty now?

There's just no way, other than increasing the size of the college, which is politically the most difficult thing—it's worse than sequestration, it's worse than anything that you can imagine. Well, we have just decided to do that because I've got no way to deal with it. There is just no way to deal with it at all.

So could we use help from Federal and State levels to be able to fund additional positions? Absolutely. That would be huge. And you know, we're a tiny place, but the issue is the same at UCSD, the whole UC system. It's the same.

Senator CANTWELL. University of Washington. So——

Dr. KLAWE. University of Washington.

I mean, we're all seeing it. And we basically can do one of two things. We can cut the number of slots so that we don't kill our faculty, and that's not meeting the needs of the nation; or we can let our course sizes grow to a thousand people in a classroom, which is not good either. So I think help from the Federal Government would be enormously appreciated.

Now let me talk about efforts to provide more exposure to young people about how cool and, yes, Chairman Rockefeller, you're absolutely right, computer science is incredibly fun and cool and creative and anyone can do it.

Right now there's an organization called Code.org that is working really hard to provide opportunities at both elementary school, middle school, and high school for students to learn how to code. And I'll also tell you that my favorite programming language is not C++ or Java, it's Python. Now it's not because my son met his girlfriend at a Python meet-up. It's because Python brings many things to the table that Java and C++ and other programming languages don't. One is, it's much more forgiving. It's much easier to learn. It's something that certainly a fifth grader can learn, whereas C++ and Java, as you know, are not.

Senator CANTWELL. Yes.

Dr. KLAWE. But two, it's actually used in industry. It's the favorite prototyping language of most software developers. They'll develop it first in Python and then they'll take the parts that need to run fast and they'll recode it in C++ or Java. Once you've learned Python, you can get a summer job, which is really important to many of our young people, particularly people from low-income backgrounds.

So there are efforts out there. There are many initiatives. But the one thing that's not there in most places is a requirement to take some computer science either in middle school or in high school. And we need it. So yes, that would be a wonderful thing to have happen at the State level and any help from the Federal Government would be very, very welcome.

Senator CANTWELL. Thank you.

The CHAIRMAN. That's it.

Senator CANTWELL. Thank you, Mr. Chairman.

The CHAIRMAN. Senator Klobuchar.

STATEMENT OF HON. AMY KLOBUCHAR, U.S. SENATOR FROM MINNESOTA

Senator KLOBUCHAR. Thank you, Mr. Chairman.

Well, I'll start again here with Dr. Klawe. And I was, when Senator Cantwell and I were talking while you were talking about the lack of women in computer science, I was remembering back to my days in college in 1982 when I learned a very hard computer program. Because back then it wasn't easy, and you had to learn all the function keys so that I could type my senior essay. And I would walk a mile to the computer lab at Yale and type in this senior essay.

And there was a group of guys that ran the computer lab, it was the only lab I could use, that ran it; and they would control it centrally, and they would play jokes with me and turn things upside down on my screen. So maybe it wasn't as welcoming for women back then in the area. But the best part of the story is I was one of the few students who learned it that wasn't in science, and so I typed umpteen senior essays for a dollar a page at the computer lab when I got mine done. So it was a marketable skill.

But just on that topic of women, I know you were recently in Minneapolis for a conference on the topic, and I think our state is ahead of the curve, as you know we are the home of many major Fortune 500 companies including innovative companies like 3M and Medtronic and we have a very high number of women in the workplace.

But what more can we do when we see in the American Association of University of Women, between 2000 and 2008 reported there was a 79 percent decline in the number of incoming undergraduate women interested in majoring in computer science?

Dr. KLAWE. Yes.

Senator KLOBUCHAR. And I know you haven't seen that. And I'm comparing this. I'm looking at this not just from some feminist standpoint, because I think this is where a lot of the high-paying jobs or the future of these skills are going to be necessary for women to do well, but I'm also looking at it as job needs. Because my state is down to 5.1 percent unemployment. We have job openings. And I have many managers tell me, how do we get more women into either manufacturing, science, or into computer science?

So if you could address that.

Dr. KLAWE. Thank you.

And yes, the conference was not the only time I've been to Minneapolis. I've been there many times. I was on the Geometry Center Advisory Board for 5 years back in the 1980s. So let me talk about what it takes to get women into computer science. It's really not particularly difficult, but it does require consistent, coherent, persistent work on the part of both the people teaching and the people in the workplace who hire women.

For whatever reason, and I have no idea of whether this is something that's biological or something that's just part of the culture of our society—I suspect it's the second though I really don't know—most women who are working in areas where women are underrepresented, so that means essentially all technology careers, suffer from something called——

Senator KLOBUCHAR. And in Congress.

Dr. KLAWE. And in Congress, yes.

Suffer from something called the imposter syndrome. You don't, Senator, I'm sure, I hope, but I do. And it means that no matter how successful you are, you constantly feel like you're a failure. And one of the problems with this is it means that women—both as students majoring in an area like computer science or engineering or as young people or senior women in a tech career—are more likely to leave when something goes wrong.

So we have a retention problem. And one of the things we do at Harvey Mudd College, and I do it every single year to the incoming classes, is I talk about the imposter syndrome. And I talk about the fact that, yes, we have a very rigorous curriculum and well, almost every kid who attends the college was the smartest kid in their school. But you're going to feel pretty much within the first week, many of you, that you don't belong here. So we talk about that, and we talk about providing support.

We make sure that in our classrooms we don't have a couple of guys in our intro classes acting like they have been programming since they were three. And maybe they were programming since they were three. We handle that by having our instructors talk to these young men. They say, "Joe, I love having you in my course, you're one of the best prepared students I've ever had, I love talking to you about everything you know; but if we could just do it in private because when we do it in public, it intimidates a lot of the other students. And we know that you don't mean to do that, all right?" The problem goes away. It just goes away.

We stream our classes. Our school colors are black and gold. We have CS5 Gold, which is for the students who have no prior computer science experience—that's the vast majority of our young women, but it's many of our young men, particularly our young men of color in that class as well. Then we have CS5 Black, which is for the students who have a lot of prior experience.

Senator KLOBUCHAR. OK. I just have one quick other question——

Dr. KLAWE. Yep.

Senator KLOBUCHAR.—because I'm running out of time. I'll ask you, Mr. Droegemeier, if you could, Doctor, if you could tell me, given that our Federal Government's spending is a percentage of GDP and a percentage of the Federal Government has declined over the last few decades and other nations are surpassing us for R&D and science; is there some ideal target that you would like to see for Federal support of R&D as a percentage of GDP?

Dr. DROEGEMEIER. That's a great question, Senator.

I think overall R&D is about 0.8 percent, 0.8 of 1 percent of GDP, and about, if you look at research, it's about 0.4 percent. I think we would like to see that comfort level to be around 1.5 percent to 2 percent of GDP. I think historically it was, you know way back when, it was up around that level. And to get back there would be incredibly helpful.

Senator KLOBUCHAR. Very good. Well, that was specific and quick.

And Senator Pryor and I are interested in the Python meet-up, Dr. Klawe, so we will ask you that in some questions that will be submitted later about what that is. Thank you.

[Laughter.]

The CHAIRMAN. Thank you, Senator Klobuchar.

And now Senator Johnson.

STATEMENT OF HON. RON JOHNSON, U.S. SENATOR FROM WISCONSIN

Senator JOHNSON. Thank you, Mr. Chairman.

This is a pretty interesting discussion. As long as we're kind of going back in history in terms of our experience, I know when I chose my career, I chose it based on whether I could get a job and what that job would pay. Now I ended up going through accounting, business school, and then—but I fully understood that people that did the harder work, but not necessarily the coolest classes or the easiest classes, but, you know, went into physics and the sciences, were going to make more money.

So I guess from my standpoint with what should be incentivizing our kids to get into college would be to actually be able to have a career, make a good living, have a successful life. Somehow we have a disconnect on that now. What—why? What's happened?

Dr. Perlmutter.

Dr. PERLMUTTER. Well, I think it's actually, you know, it's a combination of effects that we're—that we have just been talking about. You know, the fact that right now it's much less clear what kind of career you would be lucky to have in, for example, in the basic sciences than it was when I was starting out. And in fact, even worse than it was, you know, 10 years before me. So I think we see that that's going on.

But what's interesting is that I think what's motivating the people who were going through the very basic sciences is also just a possibility of a, the fun of exploration, the fact that they'll be able to try to, you know, invent the new things and create the new things and discover the new things. And that is also becoming a much more discouraging scene as we've been all discussing. It's——

Senator JOHNSON. Do we have any problem filling our college of engineering with foreign students?

Dr. PERLMUTTER. You can always find people from abroad today for——

Senator JOHNSON. Well, what attracts them? What incentivizes them to come over here and fill up our engineering—colleges of engineering?

Dr. PERLMUTTER. I think we still have the reputation of a very strong educational——

Senator JOHNSON. Sure, I understand, but—why they want to come here, but why do they want to take engineering courses——

Dr. PERLMUTTER. Oh.

Senator JOHNSON.—as opposed to——

Dr. PERLMUTTER. Yes.

Senator JOHNSON.—fill-in-the-blank studies courses which so many of our students are doing? That, you know——

Dr. PERLMUTTER. No, and I think in most of the world I think the way to, you know, a great career is still to become technologically capable. And then you could, you know, if you have that computer science degree, if you have an engineering degree, and, in fact, if you have a physics degree you can find top jobs back home if you have your American credential.

Senator JOHNSON. OK.

Dr. PERLMUTTER. It's—now it's just become much, much harder to do that if you stay in America.

Senator JOHNSON. OK. I think the point I'm trying to make, as a fiscal conservative, I really believe the Federal Government has a role in basic research because there's no profit motive and we certainly have a history of that really benefiting our economy and really benefiting the world.

But, you know, the Chairman brought up sequestration, he called it a slowly growing cancer. Now I would argue the slowly growing cancer in America is a growing culture of entitlement and dependency that is then resulted in a $17 trillion level of debt. And you know, you guys can do math, but let me tell you the ugly math that those of us that are highly concerned about this are dealing with.

From 1970 to 1999, the average interest rate the Federal Government paid on its debt was 5.3 percent. A pretty reasonable interest rate, right, about what we'd pay for mortgages. The last 4 years because we've been printing money, the average interest rate has been 1.5 percent.

Dr. PERLMUTTER. Right.

Senator JOHNSON. Now let's do some math. If we revert to that 5.3 percent interest rate, which the CBO says we'll do in 10 years, but it could spike if we're no longer the world's reserve currency, if we can no longer print money. You take 3.8 percent differential times 17 trillion dollars worth of debt, that equals 650 billion dollars.

So to a certain extent we are whistling by the graveyard here asking for additional funding paid for by what? Additional debt on the backs of our kids and grandkids?

I mean, I'd love to be talking about spending money on basic research and this, that, and the other thing. Until we face that very hard truth about what we are really doing to our country, what we are really doing to our children's future when we're talking about educating our kids and giving them an opportunity. We are stealing the opportunity and future prosperity for our kids.

So listen, I don't like sequestration. I did not vote for that bill. I thought it was a pretty mindless approach. But until we also start wrestling with the fact that two-thirds of our budget is off budget, is on an automatic pilot, is out of control; until we bring that under control, until we actually admit we have a problem and start properly defining it; these discussions, pretty interesting academic discussions, but, again, we are truly doing a service to our—disservice to our kids.

And just, oh, by the way, as we entice them into taking on collectively a trillion dollars of student loan debt and offering degrees in fill-in-the-blank studies program, that I am sorry, employers are not valuing; we're making it easy for them to not take the hard choice and understand the fact that, you know, you are going to have to get a job. And you would be better off getting a job in an area that actually will reward you properly.

So those are the incentives that I think we ought to be talking about. And I'm all for designing classes so they're fun and cool, but achievement really requires rigor and hard work, and that's the message we need to start really conveying to our young people.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you, Senator Johnson.

Senator Scott.

STATEMENT OF HON. TIM SCOTT, U.S. SENATOR FROM SOUTH CAROLINA

Senator SCOTT. Thank you, sir.

Thank you to the panelists for being here today and providing us with a lot of thoughts to think about. One of the things I'm thinking about immediately is how to pronounce your last names.

Dr. KLAWE. Klawe.

[Laughter.]

Senator SCOTT. Because there's not a single one of them I can pronounce without asking that question. I've heard 15 different ways of pronouncing it and only 14 people have spoken. So that's part of my challenge.

I will tell you that what Senator Johnson just talked about, I find quite relevant, which is the number of applicants that are applying to our universities from outside of the country and inside the country.

And I'll tell you my nephew just graduated from Georgia Tech last year. And I believe the number was 70 percent of the applicants for their, I think it's their masters degree level courses come from outside of the United States; but their new online masters program, 78 percent of the applicants come from within the United States.

So Dr. Klawe? Dr. Klawe?

Dr. KLAWE. Klawe.

Senator SCOTT. Klawe, yes. So Senator Rockefeller was right indeed then, Dr. Klawe. Can you talk to me about some of the successes that would be necessary to create an online environment that would be conducive to seeing our colleges populated with students that come from America if we had more access to it?

My nephew went to a math and science high school. And so his natural inclination led him to look at Georgia Tech as one of the destinations he wanted in—for college.

I would love to hear, I know that Khan Academy seems to be a success story. I wonder how do we create that type of accessibility through online education. If you'd talk to that a little bit, I'd appreciate it.

Dr. KLAWE. Thank you.

The first thing I want to say is that making something cool and fun doesn't mean that you're taking away the rigor, all right? They're not in opposition. So let me talk a little——

Senator SCOTT. Well, my nephew finds it cool and fun to be up at 3 a.m. studying for the next day's exam. So——

Dr. KLAWE. I like it. That's what our students——

Senator SCOTT.—I'm going to poke fun at him.

Dr. KLAWE.—do all the time.

Senator SCOTT. Thank God he did it.

Dr. KLAWE. And I also just want to say that we're number one for return on investment according to pay scale, which compares lifetime earnings against the debt that you graduate with.

So let me talk about online learning. Yes, Khan Academy has gotten a lot of press and yes, a lot of people use their website; but if you actually look at the result of what people are doing, it's not so much of watching the videos, they're actually doing the online exercises and taking the tests.

And I think that the future that we will see in terms of online education is providing activities that combine personalized learning, a lot of interaction, communication amongst small groups, as well as watching lectures taught by some of the most inspirational, not just Nobel Laureates like this guy, but also some of the most inspirational students.

So one of the things we are doing right now with funding from the Gates Foundation is to do a massive open online course, a MOOC, for AP Physics C and also for exploring computer science. Not so much so that we'll have gazillions of students taking them from high schools, but so that teachers who would like to be able to teach that course could use our materials.

And we're going make sure that we have African-Americans and Hispanic students and females and males and Caucasians and Asians actually doing the demos in this course. So that we're also going to be showing off students from Pomona, which is just next door to Claremont, who are basically 50 percent African-American, 50 percent Hispanic, taking these materials and using them. So that we can show that yes, it's fun, but yes, you don't have to be white or Asian to be really doing well at this kind of stuff.

So it's the combination of inspiration, interactive activities, and getting rapid feedback on what you're doing that will make these kinds of courses attractive to students all over the country.

Senator SCOTT. Thank you very much.

Dr. Tang.

Dr. TANG. Tang.

Senator SCOTT. Tang. Hot diggety dog. There seems to be a lot of discussion and efforts in the past and present to help bridge the gap between scientific research and product development. To make a real impact on our economy, I'd love to hear your thoughts on perhaps the weakest links in the process of technology transfer and economic development. Perhaps talk for a second or two or 26 seconds actually on the impediments perhaps.

Dr. TANG. Certainly, Senator.

Well, the pathway between basic research and commercialization is not a linear pathway by any means.

Senator SCOTT. No doubt.

Dr. TANG. It's a very tortuous pathway. Today I think the biggest gap is in the area referred to as proof-of-concept funding, which is to do enough validation that the concept in the laboratory can be successful in the marketplace. That's an area that's not getting enough investment from the venture capital world.

As the Nation and the world have become more risk averse, they view that area as not investable because the returns are too speculative and the horizons for payback are too long and the exits are nonexistent.

So we can't afford to have a pipeline of innovation that stalls because there's no proof-of-concept funding. And so therefore, that's become a domain of technology-based economic-development organizations like the Science Center to jump into the breach, because we don't require those return on investments and we can look at the developments as a pipeline, if you will, for new jobs.

So that to me is the biggest missing link today. We need more risk capital in the marketplace to be able to fund these ideas. And as a result, you know, we have to be very creative.

Senator SCOTT. Thank you.

Mr. Chairman, thank you, sir.

The CHAIRMAN. Are you sure that's all?

Senator SCOTT. I'm sure, that's all.

The CHAIRMAN. OK.

[Laughter.]

The CHAIRMAN. Senator Blumenthal.

STATEMENT OF HON. RICHARD BLUMENTHAL, U.S. SENATOR FROM CONNECTICUT

Senator BLUMENTHAL. Thank you very much for being here and welcome to Washington.

I see by the smiles on your faces——

The CHAIRMAN. Yes, what a nasty thing to say.

Senator BLUMENTHAL. Well, I say that, I'm new here, too. And you know, a lot of the debate on this issue depends on how the question is phrased. If we regard the spending that's been described earlier and the deficits and the financial challenges that our Nation faces and we have to face them as being out-of-control spending, that's one way of looking at the picture.

What we're talking about here, I think, is an investment. An investment in research, in the skills that produce better research, the skills of young people. Rather than stealing from their futures, in fact, enhancing and enriching their futures.

And so this Act, the America COMPETES Act of 2007, I think, is an enormous step forward. I can take no credit whatsoever for it. I give full credit to our chairman and other leaders who have really broadened our vision and had the courage to really stand up and speak out, as you do in your communities, meaning your intellectual communities, your university communities, and your professional communities. And I want to salute and thank you for doing so.

I don't know whether Ronald Reagan has been quoted yet today, but he said, and I'm quoting, "although basic research does not begin with a particular practical goal; when you look at the results over the years, it ends up being one of the most practical things government does."

And at an age where the capacity of government to get things done is in question and widely doubted, I think that is a truth that is undeniable about what government can and should do. Investing in basic research is one of those things. And yet my understanding is that the United States global advantage in research development is, in fact, receding in terms of our economic competition.

The Federal Government funds 31 percent of all R&D in the United States, and we are behind other nations in terms of what we invest in R&D as a percentage of our gross domestic product. So focusing on one of the areas that concerns me greatly as a member of the Armed Services Committee, as well, as this committee, national security, particularly cyber.

There is an area where the Federal Government has a distinct and undeniable responsibility, and I wonder if you could give us, I'm not going to ask any particular witness, but maybe if you could give us your assessments of where we are on basic research for our national security, in particular cyber.

Dr. KLAWE. Maybe I'll take that one. I would say that this is a critically important area. I think virtually every high-tech company has been hacked into by the Chinese. And in many cases it was only with the help of Federal cybersecurity teams that companies actually found out that they'd been hacked into.

My sense is that we currently still lead the world in terms of the kinds of areas of computer science that you need to do this, but that a lot more funding is needed and that China is investing huge sums in this area. And, you know, I think it's really important that it's funded both through NSF and through DARPA. I think it's of critical importance to the Nation. And it gets more important every day.

Dr. DROEGEMEIER. Yes, if I could respond just briefly. NSF is the primary funder of all computer science research in this country, I think about 80, 75, 80 percent; and it has a major initiative that is in line with the Federal initiative in cybersecurity; but also the networking information technology R&D program, which has been around for quite some time is a major flagship program, as well.

So although NSF doesn't do classified research, fund classified research like places like DARPA, a lot of the very fundamental research in cryptography and the things that really lead to the systems that we depend on for our security today are really funded by NSF.

And finally, NSF has a new cyber infrastructure framework for the 21st century. Infrastructure being very broadly defined; people, physical systems, technologies, and so on. And that is a big part of the CIF–21 framework, as well.

Senator BLUMENTHAL. Thank you. My time has expired, but I, again, I really want to thank you, each of you for your great work. And thank you for being here.

Thank you, Mr. Chairman.

The CHAIRMAN. Thank you, Senator Blumenthal. Senator Schatz.

STATEMENT OF HON. BRIAN SCHATZ, U.S. SENATOR FROM HAWAII

Senator SCHATZ. Thank you, Mr. Chairman.

Thank you very much to the panelists for offering your views. America COMPETES provided bold direction when it was first passed in 2007 and reauthorized in 2010 by addressing innovation, coordination, and STEM funding for research. The COMPETES report provides an assessment of where we stand.

I want to first talk about some of the findings of the report, in particular STEM education. As you know the administration recently proposed a consolidation of STEM programs. And many Senators were concerned about the effect of consolidation on the blossoming programs in various communities. For example, in Hawaii, people are really learning science through culture and culture through science. And I've seen it with my own eyes with my own children and across the Department of Education in the State of Hawaii.

And I and many other Senators objected to the administration's proposal because we were fearful that it would extinguish the great momentum that is occurring in lots of communities across the Nation. As a result as you know, no action was taken to implement the consolidation proposal in the Senate version of the bill. But this proposal from the administration is not without merit.

The idea behind it was essentially efficiency, allowing all communities to compete for these funding resources where they're not necessarily available to every community, to every nonprofit, to every agency. And finally, sort of a QA piece, standards and an assurance that these STEM programs are meeting minimum standards. Many of them are excellent. But the consolidation piece would have actually helped us to make sure that all of them were meeting minimum standards.

So this is a question for all of the panelists. Can you talk about the balance that needs to be struck between the administration's very reasonable goals of trying to get efficiency, accountability, and fairness, but also, you know, not stifling the innovation and the exciting thing that is happening?

And one other aspect of STEM education that I think is so important from the standpoint of Hawaii, but really from all of our communities is that a lot of it is place based. A lot of it is grounded in the culture and the community in which it occurs. And that's a way to plug kids into science who might not otherwise be interested. But there's a tension there, and I'd like you to talk about it, maybe starting with Dr. Tang.

Dr. TANG. Thank you, Senator.

So I'll refer to your comments on learning through culture. At the Science Center, we are advocates of STEM education; science, technology, engineering, and math. But we are also advocates of STEAM education; that's science, technology, engineering, art, and math. What we found, the cliff that I think Dr. Klawe spoke about, girls studying science subjects, typically if they're not interested in the sciences as traditionally taught by the 8th grade, you lose them for the rest of their lives.

So by introducing the arts into STEM education, it allows for right-brain/left-brain thinking in meeting their interests where they are. And so I think that's very important. The construct we have for science, technology, engineering, and math education today has sustained us very well to date, but I think we all are aware that other nations are overtaking us in those areas. And so we have to find a way of being appealing and accountable to the interests of our children to get them interested in these areas.

Senator SCHATZ. Thank you.

Dr. Klawe.

Dr. KLAWE. It turns out that one of our explore computer science projects for middle school students are going on in Hawaii. And we had something like 20 middle school teachers working with us this last summer. I'm a very big believer in allowing teachers to personalize what they're doing for their students. On the other hand, I'm a very strong supporter of the common-core standards because they're not in conflict with each other.

If you set a set of objectives for what our students should learn, but then give the teachers the professional development and the freedom—and I have to tell you I think No Child Left Behind is awful legislation because it has resulted in so many of our teachers teaching to the test. You really want teachers teaching to the students, not to the test.

So I support a blend of setting high rigorous standards and empowering teachers to really teach to the students they have to achieve those.

Senator SCHATZ. Thank you.

Dr. PERLMUTTER. I should preface some comments by just saying that this is not an area that I've looked at very closely myself, but I have been hearing the concerns from the science community that if you consolidate all of the science education in a place where the scientists don't live, then you'll, it's very easy to lose touch with the cutting-edge science world. And so the concern has been that, you know, the NIH scientists were actually getting quite involved in teaching, you know, their areas. And the NASA scientists were getting involved in teaching things that had to do with their areas. And that if this is all moved out of their orbit, you know, to some professional, you know, group that is not necessarily from the science side, that you can lose some of the whole point of science education.

So this was just one extra concern that had a very similar flavor to the one you're describing in terms of the cultural, you know, engagement that you're describing.

Senator SCHATZ. Thank you.

Dr. DROEGEMEIER. As you can imagine, Senator, NSF watched with great interest the consolidation of the programs where NSF was provided the undergraduate and the graduate programs. I can tell you right now the National Science Board is working with NSF leadership on a really kind of a deep dive into the education-research portfolio at NSF, which is about $830 million, so it's one of the bigger directorates.

And so it's something that's getting our attention right now. And in fact, we'll be meeting here in a couple of weeks to really do the next big dive to see really where that program can go. And so we're looking quite intensely at that very important problem.

Senator SCHATZ. Great.

Thank you, all.
Thank you, Mr. Chairman.
The CHAIRMAN. Senator Markey.

STATEMENT OF HON. EDWARD MARKEY, U.S. SENATOR FROM MASSACHUSETTS

Senator MARKEY. Thank you, Mr. Chairman, very much.

Massachusetts, we are number one in math, verbal, and science at the——

The CHAIRMAN. Oh, what a way to show off.

Senator MARKEY.—4th, 8th, and 10th grades.

[Laughter.]

Senator MARKEY. And we have a high percentage of minorities. We're number one at 4th, 8th, and 10th; math, verbal, and science. If we were a country, we would be 6th in the world behind Finland, Singapore, but we'd be number 6. Our little 6.5 million people up there.

We see it as part of a plan, a business plan actually. The higher the education level of these kids, the more likely they're going to get hired by the companies that have been looking for a workforce, that they are then going to be able to place their company where it is, that the kids who have the highest scores on math, verbal, and science at the 4th, 8th, and 10th grades are going to get hired. So we see that as a little business plan.

And when it comes to research and building a strong base for America's high-tech economy, I am concerned about three things. Number one, is that we're starving America's innovation engine of funding through sequestration and mindless budgets cuts. We can't have an honest conversation about research without acknowledging that elephant in the room, sequestration.

A high-tech economy like ours needs research investments to keep the innovation pipeline stocked, period. We need to stop playing budget games which undermine our Nation's long-term economic competitiveness. And that is the subject of our hearing today.

Massachusetts is 2 percent of America's population. We have a business plan. You are the business plan. America is 4 percent of the world's population. That has to be our business plan. We can't compete with these other countries in these other areas. If we don't have a business plan that involves what you all are talking about here today, then we're going to lose because the other countries are coming.

You don't have to fear China, but you should respect them. They have a plan. The others have plans. We need a plan. And you have to understand the plan.

Second, we must continue to support high-risk high-reward discovery. We must support science for the sake of science even if there is not necessarily a specific commercial application in sight. Doppa.net was not intended to create Google, eBay, Amazon, Hulu, and YouTube, but it did. Well, cracking the human genome was not intended to create companies all over America, but it did. There were other purposes that originally were just rooted in basic science and technology, but you get the payoff if your country is the one that is making the investment.

And third, we need to look at public-private partnership models and help get innovation out of the lab and into the factory. We have some deeply entrenched industries that do not invest in innovation. That's the paradox of them. OK. They might be the world's leaders, but then they don't even invest in innovation of the future because they're happy with their monopoly or what they think is their monopoly until some young kid, you know, comes up with the idea; but we have to create the conditions whereby that kid is getting the education they need and access to the technologies they need to crack the monopoly, because we have to keep our lead competitively over the rest of the world, over their kids who are going to be thirsting to make these changes that are going to be made.

You just can't hold on to a technological lead. You just have to keep moving. We have some basic history on this. We know it's all part of ensuring that there is an adaptation to new business models. We have to keep keeping the pressure on. In those sectors we need to look at ways of partnering with our innovators on proof-of-concept and demonstration projects so that more breakthroughs can bridge the valley of death and reach the market.

And I know that's something that the chairman is interested in, that Mr. Thune is interested in, and I think we should be able to do something, you know, that reflects that in the legislation that we are considering.

I actually have a bill that I plan to introduce soon that would address the issue that leads to, you know, kind of solving this valley-of-death problem. And I think we have to do it if we're going to be successful. And I'd like to work with you on that.

Dr. Tang, do you agree that there is a legitimate government role here to partner with the private sector to prove out and demonstrate new technologies?

Dr. TANG. Senator, absolutely. I think the—it's—let me go back to what you said about the plan. Unless we view the combination of STEM education, basic research, translational research, and commercialization as a continuum and all part of an economic development plan overall, I think that we'll miss key components that continue to make us successful.

So part of what you mentioned in part—in public-private partnerships is that that, I think, has to be part of the plan, as well. There have to be incentives to perform and sustain programs that can help by combining the private sector, government, and nonprofits.

Senator MARKEY. So, Dr. Tang, do you agree that supporting translational research and proof-of-concept activities increase competition in the market and help to overcome the types of corporate risk aversion that keep promising technologies bottled up?

Dr. TANG. Absolutely. I—and I noted earlier, I think that is the key missing part of the plan right now, is there are promising developments in the laboratories, in our great academic institutions that don't see the light of day because there is not that risk capital to provide proof-of-concept funding and further that development.

Senator MARKEY. You know, I've heard from many of scientists in Massachusetts that they first got interested in when they were taken over to the Boston Museum of Science when they were kids or——

Dr. TANG. Yes.

Senator MARKEY.—over to the Boston Aquarium when they were kids and they were kind of excited by the science that they saw there and a kind of light bulb went off and they said, let's think about that as a career.

Can we help to increase the diversity of our future science and engineering workforce by having more education outside of the classroom? So that we're, you know, encouraging and inspiring kids.

Dr. Klawe.

Dr. KLAWE. Absolutely. Informal science education, which is what goes on in museums and after-school clubs and all kinds of other things is an important component. However, it's most effective when it's actually tied, when it's combined with formal science education, as well. So it's a great thing when a teacher will actually take her class on a field trip to the Boston Science Center and then come back and actually teach material that ties into what they experienced there.

Senator MARKEY. Yes. And you know, it's kind of part of the modern era that we're in that you have members of the Senate and the House just kind of mocking basic research, you know, like it's not special, you know. Why should we tease that out and just make sure that we keep that on the front burner, you know. Who cares if the National Institutes of Health get cut 7 percent a year for 9 years in a row, you know.

That—will that impact on finding the cure for Alzheimer's or heart disease or—no, no, the private sector will go and do it anyway even if there is no commercial likelihood that they're going to get a reward for doing it. So why do we do this? We do it so that, you know, we encourage the best and the brightest to go into these fields. You know, you have to create a draw so that they come over here because they can use the same 800s in their boards to write an algorithm for a hedge fund that doesn't contribute one iota to the overall productivity or well-being of the planet.

And they're equally drawn as they're going through educational process over to this other early payoff financially set of companies that will draw them away. So you need to have the basic research if for no other reason than you're going to draw the kids over there.

But let me give one other practical example. Last year in the United States we spent $131 billion on Alzheimer's patients. And the chairman and I, we've both had personal experiences with this disease. $131 billion. The entire defense budget in our country is $600 billion. So Medicare and Medicaid paid $131 billion to some of the 5 million families that now have an Alzheimer's patient.

Well, the baby boomers, when they're all retired, there's going to be 15 million baby boomers with Alzheimer's. So 131 times 3 is, you know, pretty much $400 billion, two-thirds of the defense budget of our country for one disease, unless we find the cure. Unless we draw the smartest kids in science and mathematics into these fields to find the cure.

And you just can't say, well, we're going to cut the budget every year for 9 years in a row, because now you're dooming our country to making it impossible to have a balanced budget in the future because you're not investing in those programs that are going to pay the big dividend for those families that dread that that disease is going through their family, or Parkinsons or heart disease or diabetes or you name it.

And you have to believe we can do it, but you have to invest in the basic science even though you don't know exactly where the payoff is. And that's why sequestration is the stupidest idea of all time. That it treats agriculture subsidies and finding the cure for Alzheimer's equally, that basic research is treated as though it's just another expendable, you know, a commodity that the government really shouldn't be in.

As though the private sector is going to do the basic research, they are not. We've learned this. And so, Mr. Chairman, I'll just end by saying this, that each year for better or worse, you know, we have Americans that win Nobel Prizes in science. And I get invited with my wife, you know, to go to just the little reception. And I'm always in awe.

And one year they asked one of the scientists, do you think we'll be able to compete against the Chinese and the Indians 30 years from now for Nobel Prizes? And the scientist said, we are here today, the 6 of us because of an investment made 30 and 40 years ago in us. We do know—we do not yet know the wisdom of this generation. That generation had the wisdom to invest.

And so that's what's in the balance here, you know, despite of how wise we are, to make the investment in the kinds of science and technology that will continue to keep America cutting edge, but also make the changes that so profoundly effect American's families.

We can't have a more important hearing than this, Mr. Chairman. I thank you for having it.

The CHAIRMAN. No, I mean, you've just spoken nothing but one piece of wisdom after another, which is typical of you.

[Laughter.]

The CHAIRMAN. I want to add on precisely to that. Because I'm not going to do something that I'm meant to be doing, because I don't know of anything which is more important than this hearing or the implications of this hearing, whether this hearing has—changes any minds, has any impact or not.

I started out talking about sequestration with some vigor, Senator Markey.

And it's horrible and it's inexorable, but something else happened which struck me, we had a government shutdown. It was not a government shutdown that lasted, you know, for 6 months. It lasted a relatively short period of time, but during that time, I think, 99 percent of all the people at the National Science Foundation were furloughed.

And in that it was an event which predictably would come to an end, because there was a political calculus that showed that it could only last so long without so much damage being done politically, much less to the country, that one could have said, well, we can work with this.

But I think you, Dr. Klawe, I think you used the word body language at one point in an earlier part of your presentation.

The body language of a shutdown haphazard, it just happened, wasn't planned, made for political purposes, shutoff by political purposes is precisely what Senator Markey is talking about. And that is, you commit yourself to something or you don't. Your students know it. You indicated that through the use of the word body language. I'm investing in you something which I perhaps am mistaken in, but you can tell a great deal from body language about that person's view of the present and of the future, whatever.

I think it's true nationally. If we can do things like have, first of all, sequester, which I agree with Senator Markey, is it's so horrible. And what scares me is that I'm not sure the American people have any idea how it aggregates and destroys unless we can shut it off.

But in this political world, one group feels that's the way you keep government small and keeping government small is an end in and of itself of celestial purpose. Not so from my point of view. What Senator Markey said, 30 years ago some people decided to invest in me and here I am today and I have a Nobel Prize; these things cannot happen haphazardly and have a good result.

I think we in America, and I'm guilty of this myself, I look at some of these things that are happening, and I think, yes, OK, America is America; we always come back, we always get out, we always have the most innovative people, people are still coming to us, we always lead in technology and all the rest of it.

And it's not that I'm beginning to doubt myself, but I'm beginning to doubt the underpinnings of the decisions that we're making and am therefore doubting myself.

People have to believe that you mean it for real and that you're investing in it for real and come hell or high water we will not be detoured. It's a national priority. If it's not a national priority, then you have a government shutdown of small consequence in terms of time, but I don't think we have any idea yet of the alteration or the diminution of the curiosity of young people, of young teachers who are working in smaller institutions who want to get an EPSCoR grant and they're going to, and maybe they're women and they can break through the ceiling and maybe they're not and they can still break through the ceiling, but you don't have to go to Harvard, Yale, or Princeton or Stanford or Boston College. That's where he's from. OK.

[Laughter.]

The CHAIRMAN. And you don't have to do that. Wherever you are, if you are good, you will be found out about and we will help you succeed. We will secure your future by investing in you. And you can only do that with money. We don't teach; you teach, but we help with money.

And so the concept of both the sequestration not being understood fully the American people or at all by the American people, not just understood fully by this Congress and not understood deliberately by parts of this Congress is terrifying. And then you add on the instance that come up, the shutdown, well, whatever it might be.

And there's EPSCOT, there's EPSCoR, there are all kinds of things that are at risk. People clearly in line to do something, clearly have their minds set on something say, oops, I can't depend on that for certain. And what is the tipping point? Is the shutdown? Is it suddenly they understand sequestration?

It doesn't matter. Whatever it is, if it doesn't work properly, they're out. And you not only lose all that you've put into them up until this point, but you lose all that you will get from them from this point.

And I worry about that, Senator, and I'm sure you do, too.

I mean, this is just such an incredibly serious business. It's discovery. It's innovation. The curiosity of minds. The curious mind feeling supported, that they're part of an elite, that they're valued by their country, they're supported by their country come hell or high water. And in simpler days that's the way it worked.

Oh, but we'll conquer that; we're America. Maybe not so certain if, as Senator Markey said, the scientist said, I can just judge where I am today because 30 or 40 years ago people believed in me and invested in me.

So that's what we in this committee have hearings like this for is to take people like Senator Markey and myself and others who are really worried about this and who really want to help it. He comes from whatever he described Massachusetts as. I come from West Virginia, which is just a bit different.

[Laughter.]

The CHAIRMAN. But I yield in no way, shape, or form. In fact, I remember facing down Erick Block, Dr. Erick Block. He was head of NSF. And I took to them the idea of EPSCoR, of giving money to not the top tier, but to others in other States so that you would have more of a collaborative we're-all-in-it-together type of atmosphere. And it's worked absolutely wonderfully except now it's going to be grabbed by sequestration. And 99 percent of the NSF people were furloughed during those several weeks.

We're such a great country. We have so much to be proud of. People that come to this country and stay. We have to protect it. I'm really trying hard not to make a speech here, but we have to protect it. We just absolutely have to do it.

And you have to help us by involving your folks who fund you and who you have access to, to put pressure on the Congress to get rid of this ridiculous thing called sequestration. It will not go otherwise. Because there's a tool that those who want to keep cutting government have and it's locked into law and all they have to do is filibuster and we can't get 60 votes to overcome that filibuster and so sequestration goes on and on and you go down and down, which is what we do not want.

So I guess I challenge all of us that we have to overcome this. And the tipping point may not be that far off. And I have every right to be nervous and a bit scared about it and with a vast desire to do something about it.

And so I thank all of you very much for coming and for putting up with us. And this hearing is adjourned.

[Whereupon, at 4:34 p.m., the hearing was adjourned.]

A P P E N D I X

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. JOHN D. ROCKEFELLER IV TO DR. KELVIN K. DROEGEMEIER

Question 1. According to a recent survey of scientists performed by the American Society for Biochemistry and Molecular Biology, 53 percent of respondents have turned away promising researchers due to a lack of funding and 18 percent are considering moving their research outside of the United States. Last year, a CEO of a major U.S. corporation was quoted as saying that his company was expanding abroad due, in part, to the "moribund interest in science in the U.S."

How would you describe the long-term effects of lower funding in terms of training the scientific workforce, attracting and keeping top talent, and supporting innovation and have you started to see these effects already?

Answer. Since the end of World War II, the long-term, forward-thinking commitment of Congress and multiple Presidential administrations to supporting transformative basic research and the education of our next generation of scientists and engineers has underpinned our national health, security, and economic prosperity. At the present time, the U.S. is the global leader in research output, producing the highest share of "highly-cited" research papers and "triadic" patents, and also leading the world in the share of value-added high-tech (HT) manufacturing and knowledge-intensive (KI) service industries.

Although the U.S. research enterprise is strong, our status as the world's leader is, without question, in jeopardy. Other countries are gaining ground on the metrics noted above as they invest heavily in their own innovation capacity. Several foreign competitors have significantly increased their funding of higher education, bolstered their investment in R&D, and increased their output of research publications. These investments by other nations have, disturbingly, coincided with a slowing of U.S. Federal investments in R&D and an increasingly uncertain funding landscape for the U.S. scientific enterprise.

Budgetary uncertainty, sequestration, and government shutdowns have deleterious effects on our scientific enterprise. Occurring in isolation, they are extremely significant. However, because they have occurred simultaneously, their combined effects are vastly more harmful. These include meritorious projects that are never undertaken, insufficient funding for existing projects that leads to a de-scoping and thus a diminution of output, inadequate training of the next generation of scientists and the loss of large numbers of individuals who might have pursued STEM as a career, and strains on facilities used for scientific research or the failure to construct facilities that could ensure a global leadership position for the U.S. (this is particularly true in high energy physics and nuclear science). The effects of sequestration are clearly evident already: the National Science Foundation (NSF, Foundation) awarded about 700 fewer grants in FY 2013 than in FY 2012. NIH Director, Francis Collins, announced that NIH would make 650 fewer new competitive awards in 2013. Fewer awards mean less research, less innovation, a smaller STEM workforce, and a decrease in national competitiveness. According to the survey you cite, about 54 percent of scientists reported they know a colleague who has lost a job.

At my own institution, the University of Oklahoma, sequestration has led to the loss of $6.4 million in competitive funding, which is about 6 percent of the total amount awarded per year to my campus. Importantly, however, this 6 percent impacted three large projects, each of which was performing extraordinary and transformative research. Such projects take a disproportionately large amount of time and institutional investment to win and start, and thus their reduction or elimination has a proportionally greater negative impact on science and personnel. Ultimately, however, the impact is felt in the loss of high-paying jobs and national capability, including, in the case of these projects, national security.

Further, scientists are less inclined to recommend a career in science to their students because the life of a researcher is increasingly unattractive, unappreciated, and unable to compete with jobs in other fields in terms of lifelong earning potential. Lower grant funding rates mean more time is spent writing proposals, rather than performing research, with lower prospects of success. Declining state support for universities leads to less time and support for research. High tuition means students will face significant debt after graduate study, and uncertain funding for research means they might not secure jobs to repay that debt. Thus, the pool of outstanding students is decreasing, and competition for those in the pipeline is intense. Uncertainty or pessimism about future budgets makes anticipating improvement notably difficult, even for the eternal optimist. If we overtly and with unmistakably clear messaging discourage our best and brightest from a career in science, we might well never recover from the leadership gap we will create. Today's Nobel Laureates in the U.S. succeeded because they were attracted to science, and because the Nation invested in them twenty or thirty years ago. If no such investments occur today, the future is predictable, and the picture is bleak.

Thus, the consequences of sequestration and stagnating Federal research budgets will reverberate well into the future. Lack of funding today means we will be without the new knowledge that seeds innovation and prepares our Nation to meet unexpected challenges. It also means diminished support for the training of our future scientists, engineers, innovators, and entrepreneurs. Finally, the lack of stable, strong research funding today will indelibly weaken the public and private institutions that rely on strong government support for civilian science. Universities and businesses will be less able attract and retain top domestic and foreign talent, U.S. businesses will be more inclined to make R&D investments abroad, and careers in STEM will be less appealing to our students.

Question 2. Some have argued that the United States should focus its R&D efforts more on applied research and less on basic research, as some other countries have done.

Dr. Droegemeier, if the United States chose not to invest heavily in basic research, could we simply import the knowledge and expertise from other countries?

Answer. Innovation is often mischaracterized as a linear process proceeding through distinct stages: basic research in universities, followed by applied research and development at the boundary between academia and industry, and then innovation within the private sector. In reality, innovations emerge from a complex ecosystem consisting of the fluid interplay of knowledge, application, development, and commercialization, all undertaken by individuals and teams working in close coordination spanning the public and private sectors. Rather than proceeding in a linear fashion, innovation has numerous feedbacks and loops that occur at different points in the process, with these points differing for different types of research.

The innovation ecosystem also includes research facilities and equipment, transportation, communication, and education systems, and is influenced by other factors, such as the business cycle, and tax, regulatory, and trade policies. Our Nation's ability to create new businesses and bolster our health and prosperity rests squarely on these interdependent components working together in mutually reinforcing ways to produce innovations. We must be careful to not oversimplify the portrayal of this complex interplay of organizations and cultures, as some try to do, for four key reasons.

First, the ecosystem is only as strong as its weakest link, and in the United States, all components have been strong historically. Such is not the case today as all elements are being weakened dramatically, some faster than others. For example, U.S. research universities are among the best in the world and a vital part of this system. These institutions have benefited from long-standing Federal support of basic research in all disciplines, forming the bedrock of our Nation's capacity to innovate. Academic research produces a deep reservoir of knowledge upon which other researchers across disciplines and sectors can draw now and in the future. And knowledge produced by basic research is just as important as the expertise it builds among students and researchers in private companies and federally-funded laboratories.

Second, the foundation for the ecosystem is basic research, the outcomes of which usually are neither predictable nor demonstrable in their tangible benefits for society. However, basic research is without question responsible for the technological, military, and economic leadership position of the U.S. in the world today. Foregoing basic research would undermine our innovation ecosystem by weakening the ability of our universities to produce the knowledge that seeds innovation and trains our current and future scientists and engineers.

Additionally, U.S. universities, particularly public institutions, often perform research and produce human capital tailored to a state or region. Universities generate local "spillover" effects in the form of industry/university partnerships, local startup companies, and the production of talent for existing and new businesses.

For example, the high tech corridors of Silicon Valley and Route 128 were made possible because of the intense commitment to basic science research at Stanford and MIT, respectively. Universities and other institutions that perform basic research produce a reliable, on-demand supply of knowledge and expertise, much of which could have national security implications. If basic research were no longer performed domestically, its availability would be uncertain and our innovation ecosystem would be wholly dependent on other countries to function effectively. That simply cannot be allowed to occur. As noted in my oral testimony, basic research allows the United States to control its own destiny.

Thirdly, different parts of the ecosystem function on vastly different time scales. A diminution of basic research capability today may, in some areas of society, not be evident for several years or even two or three decades; however, when the impact occurs, it *will* be dramatic, and it *will* be hard to reverse. We as a Nation do not understand that point because in our rich but short history, we have never experienced it. Thus, we do not believe it will occur. Unfortunately, history shows otherwise.

And finally, it is because of the strength of our national innovation ecosystem, and in particular, the preeminence of our research universities, that the U.S. already imports significant knowledge and expertise. In 2009, students on temporary visas earned about one-third of all S&E doctoral degrees, including over 50 percent of the doctoral degrees awarded in engineering, computer science, and physics. Likewise, foreign students who receive their degrees from U.S. universities tend to remain in the U.S. The proportion of foreign S&E doctoral degree recipients who report that they plan to remain in the U.S. rose from about 50 percent in the 1980s to 77 percent in the 2006–2009 period. If we fail to continue investing aggressively in U.S. basic research, we will no longer be able to attract and retain top foreign talent, thus further eroding our Nation's ability to innovate.

Question 3. Investments in the social, behavioral, and economic sciences can help to combat crime, protect people during disasters, limit the spread of disease, and improve cybersecurity. However, some policymakers have targeted the social sciences for budget cuts.

Dr. Droegemeier, can you help me to understand how social, behavioral, and economic science research benefit U.S. security and economic interests and provide examples?

Answer. Rigorous research in the social, behavioral, and economic (SBE) sciences is vital to understanding what drives the behavior, social interactions, and motivations of people in our Nation and the world. SBE research helps us understand the factors that support economic development and social stability, that drive the activities of rogue states and terrorists, and that promote the general welfare. This research helps us find ways to improve our health, educate our young people effectively, ensure public safety, and preserve the vitality of our democracy. Sound policymaking on matters, including national security and economic competitiveness, requires the insights of the SBE sciences.

The Federal Government's modest investments in SBE research have reaped large rewards for the taxpayer. The recent joint NSF/SBE-Department of Defense (DOD) Social and Behavioral Dimensions of National Security, Conflict and Cooperation initiative has deepened our knowledge of the social and behavioral dimensions of national security issues. Psychologists, anthropologists, economists, political scientists, and demographers are helping us understand the drivers of civil conflict and unstable states, the conditions that promote terrorism and other forms of extremism, and the effects of various responses to national security threats in both the traditional geopolitical and cybersecurity realms. NSF-funded SBE research has also resulted in new decision-making tools for shipping container screening, thereby enhancing the safety of our ports and shipping traffic. And NSF-funded SBE research is helping us to better understand non-verbal communications across cultures. This is vital knowledge for our troops who rely on body language cues with non-English speaking civilians overseas and for whom miscommunication can result in a dangerous escalation of an otherwise benign situation.

SBE research has also been crucial to promoting our Nation's economic interest. In the private sector, such research has enabled companies to better understand their customers and to align their products and services accordingly. For example, social science research in the fields of network analysis, decision making and user behavior helps Google maintain its edge in an increasingly competitive global marketplace. In the public sector, NSF-supported SBE research on how to reapportion the Federal Communications Commission's airwave spectrum has resulted in over $60 billion in revenue for the Federal Government since 1994.

SBE research is also critical to maximizing the return on our Nation's investments in other realms of medical and scientific research. SBE research into the barriers to the adoption of healthy behaviors is crucial if we are to capitalize on the insights of the biomedical sciences into the drivers of obesity and disease. Similarly, in my own field of meteorology, SBE research that helps us understand human responses to weather conditions and warnings provides an important complement to technological breakthroughs in forecasting, as noted in my written testimony. Both types of knowledge are essential if we are to minimize the loss of life amid storms. And the potential for additional cross disciplinary collaboration continues to grow as physical scientists and engineers recognize that they have hit "brick walls" by seeking purely technological solutions to problems driven by human behavior.

For over 50 years, NSF has helped catalyze transformative SBE research and make the U.S. the world leader in these fields. Today, NSF awards 1,200 grants annually through its Directorate for Social, Behavior, and Economic Sciences, supporting the work of nearly 7,400 social, behavioral, and economic scientists. Maintaining our Nation's leadership in SBE research is crucial to protect our country's economic and security interests, realize the full potential of our innovation ecosystem, and create public policy rooted in facts and science. The National Science Board (NSB, Board) vigorously supports Federal funding across *all* areas of research in its current portfolio and believes that targeted reductions in SBE programs will have profoundly negative consequences to all areas of science and engineering.

Question 4. EPSCoR (Experimental Program to Stimulate Competitive Research) helps avoid unfair geographic concentration of Federal research funding in large states. West Virginia, South Dakota, and Oklahoma are just three of 31 EPSCoR jurisdictions.

Dr. Droegemeier, you've been heavily involved in EPSCoR and have discussed its strategic direction. As we look forward to renewing America COMPETES, how do we ensure that students from every state and background have access to STEM education and research opportunities?

Answer. Encouraging students to engage in the science and engineering enterprise and providing opportunities to do so are vital components of continuing our Nation's long-term success. To meet this challenge, NSF has several programs designed to recruit and retain students from every state and background. For example, NSF's Research Experiences for Undergraduates (REU) program funds dozens of sites annually where hundreds of students from all around the Nation, and across numerous disciplines, assemble for significant periods of time to participate in cutting-edge research. EPSCoR-state students are fully welcomed by REU sites, and the REU program has proven successful in developing student interest and persistence in science majors.

Further, the vast majority of NSF research proposals include funding for undergraduate and/or graduate students, who participate as research assistants. Thus, whenever an EPSCoR project is funded, it is highly likely that students will be gaining access to exceptionally high quality, hands-on science education and research experiences. Additional targeted funding for students would be welcomed in the Reauthorization Act because there is no higher priority than investing in the next generation of STEM professionals as they help perform the research that will maintain our Nation's global S&T leadership.

Finally, and of notable importance, NSF has been watching with interest the rapid growth of new technologies that enable on-line access to high quality education. The Foundation already has put in place several programs that fund research into making these technologies effective for STEM education and assessing their impacts. This work should be of special value in the long run for students in rural settings or in locales where fewer options exist for obtaining a high-quality, place-based STEM education.

Question 5. I understand that you started a company, Weather Decision Technologies, based on research conducted from an EPSCoR award. Would you have been able to start this company without Federal support, and how can EPSCoR contribute to the overall economy?

Answer. I absolutely would not have been able to start WDT without EPSCoR funding.

More specifically, EPSCoR was instrumental in funding an NSF Science and Technology Center (the Center for Analysis and Prediction of Storms, or CAPS), one of the first 11 such centers created in 1989 when the program was initiated. Centers such as CAPS were designed to tackle profoundly deep intellectual questions which, according to the state of the science at the time, were thought to be unlikely or even impossible to solve. In the case of CAPS, the challenge was using computer models to predict extreme weather such as thunderstorms and tornadoes—a capability thought to be fundamentally impossible given the chaotic and unpredictable nature of the atmosphere on fine scales. The research conducted at CAPS was foundational to starting WDT, Inc.

Not only did CAPS achieve its goal, but the theories it developed, and the practical capabilities it demonstrated experimentally, are now being implemented in the National Weather Service as part of the Weather Ready Nation program. Further, an entirely new paradigm—warning of extreme weather, such as tornadoes even before the parent storm exists (the so-called Warn on Forecast concept)—offers the hope of achieving the ultimate goal: *zero deaths.* However, to the point made above, that goal will be *absolutely impossible* to achieve without an integrative focus on social and behavioral science, because an increased warning lead time must be accompanied by an understanding of how humans behave in extreme situations when given substantially more time than is available to them today. All of this from a center that dared to tackle a problem that was viewed as impossible to solve, and from Federal funding—especially from EPSCoR—that allowed the Nation to take the risk. *If we as a Nation focus only on "safe science" in which the outcomes are predictable, and if we focus only on the physical science and engineering disciplines under the mistaken notion that technology will solve all of our problems, then we will cede our world leadership position to nations that embrace a holistic view.*

The benefits of the EPSCoR investment in CAPS continue to this day in the private sector, where the company you mention, Weather Decision Technologies, has for more than a decade been developing and deploying life-saving technologies, garnering numerous awards and now employing more than 80 people in high-paying STEM jobs. Neither this company nor the promise of an hour or more of additional lead time for issuing tornado warnings would exist today, without EPSCoR funding. And this is not a unique success story but rather one of numerous examples in which Federal funding broadly, and EPSCoR funding more specifically, has created jobs in important small businesses, built wealth, improved safety and our quality of life, and spurred innovation unrivaled anywhere in the world.

With regard to the overall impacts of EPSCoR to our economy, a state's capacity to influence competitiveness requires coordination, which an integral part of the EPSCoR program. For example, EPSCoR's Research Infrastructure Improvement program supports research based on a state's science and technology plan, often in alignment with national research priorities. Since the inception of EPSCoR in 1980, the research competitiveness of EPSCoR jurisdictions has increased by as much as 41 percent. Other NSF programs, such as Innovation Corps (I-Corps) and Industry & University Cooperative Research Centers (I/UCRC), enable academic researchers to begin translation of fundamental research discoveries, encourage academia and industry to collaborate (especially regionally), and prepare students to be entrepreneurial leaders in innovation. In short, EPSCoR contributes to the overall economy by making sure that all 50 states are meaningful contributors to the Nation's innovation.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MARK WARNER TO DR. KELVIN K. DROEGEMEIER

Question 1. More than half of all basic research in the United States is funded by the Federal Government—American universities and colleges are responsible for 53 percent of this research. I believe that we should be doing more to commercialize federally funded research, where possible. However, there is a disparity between the amount of commercialization coming from top tier research schools versus lower performing schools. A recent report from the President's Council of Advisors on Science and Technology (PCAST) found that top tier schools tend to do very well in terms of funding, while lower performing schools are more constrained in their ability to commercialize their research.

One problem I have noticed is that there are a series of closed markets in terms of who controls intellectual property (IP) within universities. Bob Litan, an innovation expert, was recently quoted in Forbes noting that "one of the big disadvantages of the traditional TLO model is that the TLO exerts the entire control over which innovations reach the market, in what form, and how fast."

Another issue is that some schools have surpassed others in terms of the amount of technology they are able to commercialize. One example is the Massachusetts Institute of Technology's Deshpande Center, which has funded 100 projects totaling over $13 million. The Center has also seen the creation of 28 spinout companies that have raised over $400 million in capital.

I have worked with Senator Moran on a proposal to accelerate commercialization within underperforming university tech transfer offices as a part of the Startup Act.

What is the most aggressive thing that we can do to spur more commercialization similar to what has been happening at schools like MIT?

Additionally, do you think that crowdfunding has any role in tech transfer? I was interested to learn that the University of Utah has recently launched its "Technology Commercialization Office" which uses crowdfunding as an alternative to traditional university "technology licensing offices" (TLOs). What do you think about this?

Answer. To your first question about spurring commercialization, I do not believe that a single "silver bullet" exists, but rather, a combination of actions can be taken to dramatically improve the situation.

First and foremost, in the context of innovation, it is important to give many ideas a chance and not to judge them by inappropriate or naïve criteria. These are key precepts at the National Science Foundation (NSF, Foundation). The Foundation asks scientists to submit their best ideas then asks other scientists to open-mindedly assess their potential. NSF works hard to not pre-define the kinds of ideas it is willing to consider, and to be mindful that unconventional thinking can yield important and even transformative results. This is true not only for basic research, but also for an innovation ecosystem that allows the best ideas and entrepreneurs to flourish.

In many respects, Congress significantly catalyzed university-based commercialization activities in 1980 with the passage of the Bayh-Dole Act. Bayh-Dole aligned university incentives with societal goals in a way that made possible the establishment of MIT's Technology Licensing Office and similar offices at other universities. Because of that bill, and other opportunities driven by leaders like you, there now exists an unprecedented number of new types of mechanisms available for technology transfer. Many states, agencies, and universities also see a critical need, resulting in intense interest in replicating successes and finding more effective and efficient methods for moving innovations from the lab to the marketplace.

For example, NSF is aggressively seeking to accelerate commercialization and entrepreneurial education through the I-Corps program. By deploying a multi-scale network of nodes, sites, and teams, we hope to replicate some of the elements that underpin the success of the Deshpande Center and catalyze the development of the local and regional innovation clusters that are essential components of commercialization at places like MIT and Stanford University. NSF is also working to better connect the I-Corps program with existing SBIR and STTR programs, and other agencies are looking to implement their own versions of I-Corps.

Many of my fellow "Vice Presidents for Research" have formally added "and Economic Development" to their titles as U.S. universities engage creatively with these new ideas and diversify the incentives and arrangements offered to their faculty in order to encourage greater social contribution. In this regard, I can recommend to you a 2013 Department of Commerce report entitled "The Innovative and Entrepreneurial University: Higher Education, Innovation and Entrepreneurship in Focus." That report is filled with examples of how universities are taking new approaches to spur both student and faculty entrepreneurship and technology transfer, including my own university's Growth Fund that helps scientists develop prototypes, among other things.

I believe Congress can best help the commercialization process by continuing to incentivize a range of mechanisms and by supporting unfettered scientific inquiry. Specifically, you can help by working with agencies and stakeholders to eliminate regulatory obstacles to innovative partnerships (I elaborate on this point in one of your subsequent questions), by ensuring that the ability of researchers to pursue the best ideas is not restricted by "one size fits all" regulations, and by making sure that the creative freedom that underpins the government-university partnership is not undermined by politics or bureaucracy. Over the last 50 years, this partnership has thrived, performing over half of basic research in the United States, and creating the new knowledge that is the "seed corn" for our innovation economy.

As Dr. Litan alludes, if university administrators are the sole judges of which ideas might reach the marketplace, we may miss important opportunities. Instead, we should encourage multiple, robust mechanisms to help scientists consider whether their ideas might have market value, and then ensure that incentives exist for those researchers to invest time and thought into application and commercialization.

The University of Oklahoma (OU), in its Center for the Creation of Economic Wealth (CCEW) offers a wonderful example of this strategy. CCEW brings together students from all disciplines with a common thread of entrepreneurship courses taught in the business college—along with successful alumni businesspersons and innovative faculty counselors. CCEW has transformed the landscape of OU intellectual property commercialization and is becoming a force for regional economic development in Oklahoma.

A second, and often overlooked issue with regard to academic-corporate interactions, involves direct funding of university research by private companies. Although it is true that universities focus considerable attention on basic research, certain disciplines, such as those in engineering, also perform applied research as well as development. The amount of money coming to research universities from private companies has been essentially stagnant for the past two decades, which suggests that considerable unrealized potential exists in academic-corporate partnerships, as noted in the recent National Research Council (NRC) report chaired by Mr. Chad Holliday. In my personal view, Federal and state policies should be examined to identify barriers to such partnerships, especially with regard to the disposition of intellectual property.

Universities have spent significant sums of money to create technology transfer organizations yet the amount of revenue coming to universities from such licenses is relatively small. The principal benefit to universities from linkages with the private sector is funding for research and development, support for equipment, and stipends for students and post-doctoral researchers. Moreover, contrary to popular belief, private companies are willing to support more fundamental "basic" research in the context of work having a more applied focus—because private companies realize they too must contribute to basic research. The Federal Government cannot do everything.

If access to intellectual property by private companies that fund universities could be greatly streamlined, as is now being done by institutions such as the University of Illinois and University of Minnesota, the private sector could unlock enormous benefits from the public investment in basic research and thus dramatically and quickly transform the competitiveness of a state. Universities would reap substantially greater benefits from strategic corporate linkages than are possible today. In my personal view, a positive disruption to longstanding, burdensome practices regarding intellectual property and corporate-academic interactions could yield an impact on commercialization.

To your second question, crowdfunding engines like the one you mention at Utah can be efficient and effective at matching ideas with investors who believe in their potential. This helps with a specific, sticky part of the innovation pipeline: the point at which a scientist or university has an outcome or idea but cannot conduct expensive market research to see if it really has potential. The NSF I-Corps program addresses this and a few other sticky parts of the innovation pipeline by actively teaching researchers to think entrepreneurially from the outset. It also educates such researchers about how to build an early-stage company.

I also should mention that NSF funds scientific research that explores factors that enable innovation and diffusion of innovations. This is quite a vibrant social science topic. NSF-funded researchers have found, for example, that geographical concentrations of "star" researchers in a field are the best predictor that a given region will be an innovation "hot spot" in that field. That is, the stars themselves, rather than their disembodied discoveries or their firms, seem to be what matters most.

Others have identified some of the important social factors that impede diffusion of new, unproven technologies. There is much more to learn, of course, and the new era of "big data" promises to be a great boon to those who study this sort of phenomenon. Consequently, we can look forward to continued progress in understanding how best to promote and support innovations for the Nation's greater wellbeing *provided* that adequate funding is directed toward the social, behavioral, and economic sciences.

Question 2. According to a 2007 report by the National Academies, faculty working on Federally funded research spend 42 percent of their time on administrative duties, such as compliance with Federal regulations. Additionally, a November 2012 PCAST report states:

> "Over the last two decades, the Government has added a steady stream of new compliance and reporting requirements, many of which vastly increase the flow of paper without causing any improvements in actual performance. Sometimes these requirements stand in the way of performance improvements."

Some solutions proposed include eliminating overly burdensome regulations, such as effort reporting, harmonizing regulation across agencies, focusing regulations on performance rather than process, as well as others.

What actions should be taken to make University research regulations more efficient, while still maintaining a high level of accountability?

Do you have any specific examples of burdensome regulations that should be reformed?

Answer. I agree wholeheartedly with your concern and with the observations of the PCAST report. As a vice president for research at a tier-1 comprehensive research university, I can attest to the growing number of unfunded compliance and reporting requirements and their deleterious impact on research. I hasten to add that researchers and university research leaders understand and appreciate the importance of appropriate compliance rules and regulations. Indeed, the academic enterprise rests on the integrity of its participants. However, the important issue at hand is the extent to which aggregated regulations are appropriately structured, implemented, and evaluated with regard to their effectiveness and unintended or unnecessary consequences. It is also important to note that this is not just a Federal problem. States, accrediting organizations, and universities themselves all contribute to administrative burdens.

Reports, such as the National Academies' (Federal Demonstration Partnership) report you cite, indicate that the costs in time and lost opportunity are significant. In my view, funding scientists to perform administrative tasks instead of research is a significant waste of taxpayer dollars.

My NSB colleagues share these concerns. In December 2012, under the leadership of NSB Member, Dr. Arthur Bienenstock of Stanford University and former Associate Director for Science with the Office of Science and Technology Policy, the NSB created the Task Force on Administrative Burdens to examine this issue and offer recommendations. In March 2013, our task force issued an open Request for Information (RFI) to scientists with Federal research funding to identify those Federal and university requirements that contribute most to their administrative workload and to offer recommendations for reducing it—precisely the questions you raise. We also held a series of roundtable discussions across the Nation and have invited comment on our preliminary analyses from agencies, working groups, and organizations that can play a potential role in the current level of administrative burden and have the authority to reduce it.

It is our expectation that our recommendations and findings, which are just now being finalized, will offer a detailed and comprehensive answer to your question. We would like to provide you our full report and any briefings or supporting materials that will be of help to you just as soon as our findings and recommendations have Board approval, which should be early 2014.

Preliminarily, I can say that our findings confirm and extend many of those in the 2012 Faculty Workload Survey that you cite. Effort reporting, as you note, is often characterized as a particular source of burden. This is consistent with our preliminary findings. Our task force responded to the Office of Management and Budget Notice of Proposed Guidance Reform expressing support for effort reporting reforms and encouraging swift implementation.

Beyond this, we see wide agreement in the RFI comments that adding regulations *per se* adds burden and that fear of audits can precipitate unintended, detrimental levels of risk aversion and reporting requirements. The proposed solutions you cite—harmonizing regulations across agencies and focusing regulations on performance rather than process—also have been recommended frequently in our RFI. My colleagues and I concur that identifying regulations and requirements that lead to undue burden and eliminating, modifying, or harmonizing them is essential to improving the research enterprise and fully capitalizing on Federal investments in scientific research.

We are also highly supportive of the principle that scientific stakeholder communities need to be represented in any and all efforts to prioritize and streamline Federal regulations if we want to achieve productive reform. Scientific activities and the universities that house them have some unique, and sometimes fragile, core characteristics. If these are not considered as regulations are revised, reforms could be ineffective or even harmful.

Question 3. I am very supportive of efforts to consolidate STEM programs and funding streams. President Obama's 2014 budget decreases the number of STEM programs by 50 percent, from 226 to 112. I know that some Members have expressed concerns about this consolidation, but I believe this a great way to reduce administrative overhead and to get more funding to students.

In considering the reauthorization of COMPETES, do you have any recommendations for further consolidation of STEM programs?

Answer. The National Science Board has followed the proposed consolidations with interest. We, too, are supportive of the goals, both the efficiency goal and, particularly, the goal of ensuring that the most effective STEM education practices are identified and diffused quickly and widely across all Federal STEM educational efforts. Ongoing coordination across agencies will be essential for diffusion of effective practice. The consolidations should be done in an evidence-based way with engagement of stakeholders.

As plans related to consolidation move forward, we encourage healthy stakeholder engagement and coordination processes centered around evidence of effective educational practices. NSF has a special role to play in this regard. The Foundation is only one of a few Federal agencies that funds basic research into learning and learning environments, including valid methods for evaluation of learning, which will underpin any evidence-based approach to improving STEM education practices. The Foundation is therefore positioned to identify evidence-based research agendas that will enable the timely diffusion and coordination of effective STEM education practices in Federal agencies. This is a role that the Foundation is equipped to handle well.

Question 4. I believe that America is lacking a long-term vision for economic growth and international competitiveness. There has not been enough of an effort to come together across government sectors and devise a strategy for going forward.

I included an amendment in the 2010 COMPETES reauthorization that directed the Department of Commerce to create a National Competitiveness Strategy. However, I was disappointed by the way the process played out. I did not feel like the report did enough to concisely and effectively establish solutions for key issues like infrastructure investment, immigration policy, research and development funding, and others.

In your opinion, what targeted investment in R&D would do the most to help America stay ahead of our global competition?

What recent investments in R&D have had the most potential impact to American global competitiveness?

Answer. America's "innovation ecosystem" has propelled our success, and my personal view is that a long-term vision and strategic plan would help ensure effective stewardship of available resources and strategic emphasis on areas of greatest strength and value. Ensuring that this ecosystem retains the ingredients that have allowed our Nation's researchers, engineers, and businesses to flourish is critical to retaining our competitive global edge. U.S. researchers benefit from unparalleled freedom to pursue their best ideas; as we think about the future, we need to ensure we do not lose this critical component of our R&D enterprise.

In our increasingly interconnected, big data, high-tech world, strong, stable investment in R&D across all disciplines will need to continue. Fields of science and engineering are growing ever more interdependent in order to address large-scale and complex problems, ranging from natural resource scarcity to national security and health risks. The insights social sciences can provide us about human behavior weave throughout all these national challenges. Therefore, it is crucially important that we continue to fund *all* areas of science and technology, and that we erect no barriers between them. In fact, we need to maximize the ability for researchers in multiple fields to collaborative effectively.

We need to continue building our STEM workforce, both by investing in the training of U.S. students as well as attracting and retaining foreign STEM students to contribute their ideas and skills to our workforce. One significant aspect of U.S. innovation success lies in the creativity of our students; we must make sure that the creative edge is not lost in an environment increasingly focused on passing standardized tests, and we must continue our Nation's long tradition of attracting and retaining the best and brightest foreign-born students

We need to leverage our R&D investments with interagency collaborations that extend the reach and yield of our investments and encourage academic-industry partnerships. The Foundation's Industry/University Cooperative Research Centers are a good model of such a partnership.

Steady, predictable Federal funding will help colleges, universities, businesses, and others who perform or rely on federally-funded basic research to make wise, forward-thinking decisions that yield maximal returns on taxpayers' investments. I cannot overstate the importance of this issue. Risk taking, which is a foundational notion of basic research, simply cannot be pursued in today's environment of fiscal uncertainty. Likewise, strong, consistent Federal support is crucial to recruiting and retaining future generations of scientists and engineers. America needs its young people to view S&T as a promising career path, and without question, the emerging generation of researchers is quite troubled by the lack support for S&T and many are choosing other careers. Slowly and surely this is eating away at our competitive advantage.

Investments in R&D that figure prominently in our global competitiveness include both those geared toward generating ingenious new ideas and those focused on nurturing the next generation of innovators. As you know, due to the nature of basic research, its impact is not immediately felt. Likewise, the education and training of the next generation of scientists and engineers is a decades-long endeavor. These are both long-term investments where the payoffs come later.

Thousands of fundamental scientific discoveries made across all disciplines can be used and re-used in an almost infinite number of ways now and decades into the future to produce outcomes that have extraordinary benefits for society. R&D investments that integrate elements from multiple disciplines and technologies also have great potential. Many of the Foundation's activities focus on areas of national priority and thus lie at the heart of national competitiveness and well-being. These include advanced manufacturing, robotics, and interdisciplinary research to enrich our understanding of the brain's neural networks, nanotechnology, STEM education, global change research, and cybersecurity R&D.

Equally important is investment in the education and training of a scientifically literate, globally competitive U.S. workforce that includes scientists and engineers, who will advance our fundamental understanding of the world around us, and innovators and entrepreneurs, who will use that knowledge to create new products and new industries. STEM education initiatives, such as research into learning and pedagogy and opportunities for hands-on research experiences, are vital to developing our Nation's talent pool. Given the trajectory of demographics in the U.S., enhancing the diversity of the STEM workforce is not simply a good idea—it is essential if we are to continue as a leader in S&T research and businesses.

Finally, a modern research infrastructure is critical to maintaining our Nation's competitiveness. Through its Major Research Equipment and Facilities Construction account, NSF provides U.S. scientists and engineers with the large, shared tools necessary to perform world-class research, such as supercomputing facilities, ships, airplanes, and large arrays of observing systems to gauge changes occurring on our planet.

RESPONSE TO WRITTEN QUESTION SUBMITTED BY HON. ROGER F. WICKER TO DR. KELVIN K. DROEGEMEIER

Question. How do your mission agency STEM education programs, such as the NOAA Sea Grant education program, contribute to the competitiveness of the United States?

Answer. A STEM-literate workforce is absolutely essential for the U.S. to be competitive in our knowledge-and technology-intensive global economy. Consequently, the National Science Foundation (NSF) operates programs across its directorates and divisions to ensure a high-quality, STEM-literate workforce and citizenry and to enable universities and other organizations to produce the best, most innovative research scientists and engineers in the world. In that context, although the National Science Board (NSB; Board) does not have purview over NOAA's Sea Grant program (and likewise the NASA Space Grant Consortium), such programs provide critical training and education in STEM fields and are a fundamental component of the mission of NOAA, NASA, and NSF.

NSF currently makes investments in STEM education at every level: pre-K, K–12, undergraduate, graduate, and informal/public. Its major, focused education investments fall, for the most part, into four categories:

- *NSF Fellowships and Scholarships,* such as the flagship *Graduate Research Fellowship* (GRF), which attracts the best and the brightest of our Nation's students to STEM careers and helps enable them to complete their STEM educations. Numerous individuals funded by the GRF over its 60-year history are now members of the National Academies and some have won the Nobel Prize.
- *Basic Education Research programs,* such as *Research on Education and Learning,* that addresses fundamental questions, and produces valuable evaluative data, about how learning (particularly in STEM fields) occurs and ways to improve learning environments.
- *STEM Education Improvement programs,* such as *Improving Undergraduate STEM Education,* which translate scientific evidence and research outcomes about STEM learning into innovative materials and practices. It further assesses those innovations and disseminates the most valuable ones for implementation.
- *Research Experience Programs,* such as *REU Sites* (*Research Experiences for Undergraduate Sites*), which bring numbers of students together with leading faculty to initiate and conduct projects together. These sorts of learning opportunities can be transformative for students and faculty alike.

It is also important to note that a large majority of NSF-funded research projects, ranging from "individual investigator" awards to center activities to large, multiuser facilities, include funding for undergraduate students to participate as research assistants as they seek their B.S. degrees. Such hands-on engagement in cutting-edge science constitutes excellent STEM education in and of itself and has been shown to increase a student's likelihood of completing a STEM major and pursuing a career in science. Additionally, projects also frequently fund M.S. and Ph.D. students. In this sense, almost all NSF research investments are also investments in the future of the U.S. scientific workforce, and therefore, in U.S. competitiveness.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. DEB FISCHER TO DR. KELVIN K. DROEGEMEIER

Question 1. Oklahoma like Nebraska is an EPSCoR state, which means our states receive a limited amount of Federal research funding. Over the past three years (2010–2012), according to NSF, Oklahoma received 0.46 percent of all NSF research funding and Nebraska received 0.38 percent. At a time when technology, innovation, and research are so important to industry and job creation, how can states like ours become more competitive quickly?

Answer. As noted in my oral and written testimony, states like Nebraska and Oklahoma possess exceptional capabilities in the quality of their research universities, in the organization and prioritization of their overall research capabilities in alignment with state and institutional assets and goals, and in their ability to leverage resources, partner with others in innovative ways, and respond quickly to opportunity. Such is the hallmark of EPSCoR states.

Yet, as shown by the newly released National Research Council (NRC) report, although EPSCoR states have enhanced their competitiveness by traditional measures, so have non-EPSCoR states–thereby leaving the relative position of states like Nebraska and Oklahoma essentially unchanged. Your question, therefore, is extremely relevant: Even with EPSCoR, our states are not achieving their full potential and more must be done–as soon as possible–to help them contribute maximally to our Nation's competitiveness. Failing in this effort means that significant national potential will remain unrealized, which is not an acceptable outcome when our Nation faces continually increasing competition in science and engineering.

Embracing the full potential of an economy that is increasingly reliant on knowledge and technology entails both near-term and long-term strategies to maximize competitiveness. Although many factors influence competitiveness, a state's capacity to conduct leading-edge research, and to innovate within the private sector, are foremost among them. Building research and innovation capacity within a state requires coordinated and complementary state and Federal policies as well as forward-looking leadership.

On relatively long time scales, at the state level, investments in formal and informal education at all levels that ensure a local concentration and retention of a scientifically literate workforce, and policies that attract and retain technology-oriented businesses (*e.g.,* tax incentives, innovative partnerships, research campuses that house start-up companies and provide support for developing business plans and taking basic research across the valley of death, the provision of consulting support from university faculty to private companies) are crucial to success.

To your specific question about enhancing competitiveness *quickly,* as one example, Oklahoma created in 2003 a program called EDGE (Economic Development Generating Excellence), which was a state-wide effort to prioritize our assets and identify areas where strategic investment in research could lead to rapid job creation and enhanced competitiveness. Based upon the EDGE plan, the legislature authorized the creation of a $1 billion endowment to support research and the transfer of technology to the private sector that would make Oklahoma the "Research Capital of the Plains." Several funding competitions were held, leading to the creation of new companies and the rapid movement of research outcomes into innovative products and services, especially in the biomedical sector. Other states have enacted similar programs, and their ultimate success depends upon a close alignment of research university strengths with private sector capabilities and workforce availability and retention.

At the Federal level, innovation capacity is fostered by investment in unfettered basic research across all disciplines including the social, behavioral, and economic sciences. Further, redundant and outdated regulations must be streamlined to ensure that much of every dollar invested in research actually goes toward research. Finally, barriers to academic-industry partnerships must be removed, and incentives and support provided, so that promising research results can be innovated quickly into products and services. This is especially important given that the time from discovery to innovation is now measured in months, rather than in years.

To the point just made, an often overlooked issue with regard to academic-corporate interactions involves direct funding of university research by private companies. Although it is true that universities focus considerable attention on basic research, certain disciplines, such as those in engineering, also perform applied research as well as development. The amount of money coming to research universities from private companies has been essentially stagnant for the past two decades, which suggests that considerable unrealized potential exists in academic-corporate partnerships, as noted in the recent NRC report chaired by Chad Holliday. In my personal view, Federal and state policies should be examined to identify barriers to such partnerships, especially with regard to the disposition of intellectual property.

Universities have spent significant sums of money to create technology transfer organizations yet the amount of revenue coming to universities from such licenses is relatively small. The principal benefit to universities from linkages with the private sector is funding for research and development, support for equipment, and stipends for students and post-doctoral researchers. Moreover, contrary to popular belief, private companies are willing to support more fundamental "basic" research in the context of work having a more applied focus—because private companies realize they too must contribute to basic research. The Federal Government cannot do everything.

If access to intellectual property by private companies that fund universities could be greatly streamlined, as is now being done by institutions such as the University of Illinois and University of Minnesota, the private sector could unlock enormous benefits from the public investment in basic research and thus dramatically and quickly transform the competitiveness of a state. Universities would reap substantially greater benefits from strategic corporate linkages than are possible today. In my personal view, a positive disruption to longstanding, burdensome practices regarding intellectual property and corporate-academic interactions could yield an impact on commercialization.

More specific to NSF, EPSCoR facilitates competitiveness not only through support for basic research and STEM education, but also through targeted programs that build research capacity within states, encourage public-private partnerships, and promote technology transfer. For example, EPSCoR provides funding based on competitively-reviewed proposals to states such as Nebraska that historically have received comparatively small percentages of NSF support. EPSCoR's Research Infrastructure Improvement program supports research based on a state's science and technology plans, usually in alignment with national research priorities. Since the program's inception in 1980, competitiveness of EPSCoR jurisdictions has increased by as much as 41 percent. Other NSF programs, such as Innovation Corps (I-Corps) and Industry & University Cooperative Research Centers (I/UCRC), enable academic researchers to begin translation of fundamental research discoveries, encourage academia and industry to collaborate (especially regionally), and prepare students to be entrepreneurial leaders in innovation.

Continued, stable support for basic research, STEM education programs, and activities like EPSCoR, Innovation Corps (I-Corps), and the Industry/University Cooperative Research Centers (I/UCRC) will strengthen Nebraska's colleges, universities, and industries in mutually beneficial ways.

Question 2. Economic growth and job creation are critical to any state. I am quite proud of Nebraska's recent success in this area with one of the lowest unemployment rates in the country, many good jobs, and successful businesses. What do you see as the underpinnings for a vibrant economy and jobs in the future? How can this legislation contribute to that?

Answer. Our nation's economic prosperity rests on complex, often interconnected factors: health care, energy and energy security, transportation and infrastructure, national security, and education, to name a few. The progress of science underpins all of these. As highlighted in the National Academies' *Rising Above the Gathering Storm* report, the majority of U.S. economic growth since World War II is attributable to advances in science and technology (S&T). *The National Science Board believes this trend will continue provided that sustained, stable support exists for basic research.* Although the cynic might expect such a statement from a board whose mission involves fostering exceptional research for the nation, the facts of more than 60 years of investment attest to the pronouncement's veracity.

The progress of S&T requires an unwavering commitment to pursuing transformative basic research and developing our Nation's human capital. As noted in my written testimony, basic research is the DNA from which new innovations and technologies arise to fuel our Nation's economic prosperity, health, and welfare. That DNA, composed of thousands of discoveries made across all disciplines, can be used and re-used in an almost infinite number of ways now and decades into the future to produce outcomes that have extraordinary benefits for society.

Equally important is human capital development—the education and training of a scientifically literate, globally competitive U.S. workforce. This workforce includes scientists and engineers, who will advance our fundamental understanding of the world, and our innovators and entrepreneurs, who will use that knowledge to create new products and new industries. STEM education initiatives, such as research into learning and pedagogy and opportunities for hands-on research experiences are vital to developing our Nation's talent pool.

Although continued support of basic research and increased STEM literacy are critical, as noted above, we also need investments in projects like the "Nebraska Innovation Campus," where industry, entrepreneurs, and academic faculty work together in public-private partnerships to move discovery from the lab to the marketplace. The Nebraska Innovation Campus was created as a research campus that enhances opportunities for private business to access faculty to develop marketable innovations and the first building is scheduled to open in spring 2014.

I can attest to the tremendous potential of the Nebraska Innovation Campus because I traveled to Lincoln a few years ago to meet with the President and Chancellor to share the experiences of my own institution and its counterpart—the University of Oklahoma Research Campus. On this campus, we built a million square feet, fully occupied in less than a decade, and the Research Campus was named the 2013 Research Park of the Year by the Association of University Research Parks. NU is heading in this same direction. Such tremendous assets are very quickly becoming magnets for both intellectual and economic vitality in states like Nebraska and Oklahoma, and I urge that careful attention be paid to "research campuses and parks" at the Federal level as a means for *rapidly enhancing* national competitiveness via the close integration of government, industry, and academia (often referred to as the triple helix).

To your specific question, the Reauthorization Act can facilitate local, regional, and national economic prosperity by sustaining long-standing Congressional support for the U.S. S&T enterprise. It can do this in three mutually reinforcing ways:

- The Reauthorization Act can provide a vision for strong, stable Federal funding for basic research in *all* areas of STEM, including the social, behavioral and economic sciences. I cannot overstate the importance of that point. Basic research is a long-term investment, and providing steady, *predictable* Federal funding will help colleges, universities, businesses, and others who perform or rely on federally-funded basic research make wise, forward-thinking decisions that yield maximal returns on taxpayers' investments. Likewise, strong, consistent Federal support is crucial for recruiting and retaining future generations of scientists and engineers. These young people must view S&T as a viable and attractive career, and it is abundantly clear they will not do so unless they see, and can have confidence in, more than a few feet down a pathway of a thousand miles.
- The Reauthorization Act can enhance investment in the education and training of the next generation of scientists and engineers. To remain globally competitive, the U.S. will need an "all-hands-on-deck" approach, bringing all of its assets to bear. This means not only strengthening investments in STEM education, but also committing to efforts to ensure a diverse workforce that harnesses and reflects the Nation's increasingly diverse population. In this regard, funding for additional graduate fellowships, undergraduate research programs, and efforts that meaningfully enhance participation are essential. To the latter point, EPSCoR states like Nebraska and Oklahoma can play an especially vital role if they focus on their own specific strengths (*e.g.,* Native Americans in the case of Oklahoma) and work toward a sustainable framework for bringing underrepresented groups into STEM fields and *helping them succeed.*
- The Reauthorization Act can augment our ability to transform basic research discoveries into future innovations by fostering linkages between the public and private sectors and streamlining the process for translating research into marketable products and processes. NSF has several programs that can serve as models for this legislation: the I/UCRC and the I-Corps programs aim to stimulate academia-industry partnerships (especially regionally), leverage industrial support, accelerate technology transfer and commercialization, and prepare students to be entrepreneurial leaders. In addition, NSF's Small Business Innovation Research (SBIR) program and its Small Business Technology Transfer (STTR) program provide incentives and enable startups and small business to undertake R&D. Finally, this legislation could call for a study that seeks to understand and eliminate barriers to academic-corporate partnerships, particularly with regard to Federal tax policies that tend to tie research universities' hands.

RESPONSE TO WRITTEN QUESTION SUBMITTED BY HON. JOHN D. ROCKEFELLER IV TO DR. SAUL PERLMUTTER

Question. According to a recent survey of scientists performed by the American Society for Biochemistry and Molecular Biology, 53 percent of respondents have turned away promising researchers due to a lack of funding and 18 percent are considering moving their research outside of the United States. Last year, a CEO of a major U.S. corporation was quoted as saying that his company was expanding abroad due, in part, to the "moribund interest in science in the U.S." How would you describe the long-term effects of lower funding in terms of training the scientific workforce, attracting and keeping top talent, and supporting innovation and have you started to see these effects already?

Answer. Researchers want to conduct research. I believe it is that simple. Without adequate opportunities to conduct science, young researchers will look elsewhere. Also, younger students in high school and college still planning their careers will be discouraged from joining scientific fields without obvious employment opportunities.

My research group and many other groups around me have been forced to turn down the applications of promising researchers—the next generation of world leading scientists—as funding levels have dropped. As I stated in my testimony, for the first time in my career, I have seen examples of researchers choosing to join research groups abroad in fields in which the United States' investments have stagnated and our leadership is waning.

That said, I am encouraged by legislation such as the America COMPETES Act that if passed would renew America's commitment to increasing funding for basic research, and help us to train a next generation of world leading scientists here at home.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MARK WARNER TO DR. SAUL PERLMUTTER

Question 1. More than half of all basic research in the United States is funded by the Federal Government—American universities and colleges are responsible for 53 percent of this research. I believe that we should be doing more to commercialize federally funded research, where possible. However, there is a disparity between the amount of commercialization coming from top tier research schools versus lower performing schools. A recent report from the President's Council of Advisors on Science and Technology (PCAST) found that top tier schools tend to do very well in terms of funding, while lower performing schools are more constrained in their ability to commercialize their research.

One problem I have noticed is that there are a series of closed markets in terms of who controls intellectual property (IP) within universities. Bob Litan, an innovation expert, was recently quoted in Forbes noting that "one of the big disadvantages of the traditional TLO model is that the TLO exerts the entire control over which innovations reach the market, in what form, and how fast."

Another issue is that some schools have surpassed others in terms of the amount of technology they are able to commercialize. One example is the Massachusetts Institute of Technology's Deshpande Center, which has funded 100 projects totaling over $13 million. The Center has also seen the creation of 28 spinout companies that have raised over $400 million in capital.

I have worked with Senator Moran on a proposal to accelerate commercialization within underperforming university tech transfer offices as a part of the Startup Act.

Question 1a. What is the most aggressive thing that we can do to spur more commercialization similar to what has been happening at schools like MIT?

Question 1b. Additionally, do you think that crowdfunding has any role in tech transfer? I was interested to learn that the University of Utah has recently launched its "Technology Commercialization Office" which uses crowdfunding as an alternative to traditional university "technology licensing offices" (TLOs). What do you think about this?

Answer. In answer to both a) and b) I am quiet interested in learning more about the efforts at MIT, Utah and other institutions to commercialize research, but without knowing more I hesitate to offer an opinion on this. However, I do believe that the most important first ingredient of technology development, especially for those that are breakthrough technologies, stems from basic science discoveries. That is the reason I strongly support healthy Federal investment in basic science and am pleased that the COMPETES Act would support increased funding for this research.

Question 2. According to a 2007 report by the National Academies, faculty working on federally funded research spend 42 percent of their time on administrative duties, such as compliance with Federal regulations. Additionally, a November 2012 PCAST report states:

> "Over the last two decades, the Government has added a steady stream of new compliance and reporting requirements, many of which vastly increase the flow of paper without causing any improvements in actual performance. Sometimes these requirements stand in the way of performance improvements."

Some solutions proposed include eliminating overly burdensome regulations, such as effort reporting, harmonizing regulation across agencies, focusing regulations on performance rather than process, as well as others.

Question 2a. What actions should be taken to make University research regulations more efficient, while still maintaining a high level of accountability?

Question 2b. Do you have any specific examples of burdensome regulations that should be reformed?

Answer. In answer to both a) and b), I strongly agree with the PCAST report. Micromanagement and over regulation stifles the creativity and scientific productivity of the scientists. Although it may appear that fewer mistakes are being made, the truth is that the result is smaller scientific returns on the Federal investment. You cannot regulate your way to great science (this has been tried, unsuccessfully, by other countries). Although at the moment I do not have a list of suggestions for specific reform. However, I do believe that Congress could send a strong message to the agencies and scientific program managers by making it clear that they care more about researchers spending their productive time on science rather than on accounting processes and reporting.

Question 3. I am very supportive of efforts to consolidate STEM programs and funding streams. President Obama's 2014 budget decreases the number of STEM programs by 50 percent, from 226 to 112. I know that some Members have expressed concerns about this consolidation, but I believe this a great way to reduce administrative overhead and to get more funding to students. In considering the reauthorization of COMPETES, do you have any recommendations for further consolidation of STEM programs?

Answer. At this time I do not have an opinion on the proposed consolidation of STEM programs.

Question 4. I believe that America is lacking a long-term vision for economic growth and international competitiveness. There has not been enough of an effort to come together across government sectors and devise a strategy for going forward.

I included an amendment in the 2010 COMPETES reauthorization that directed the Department of Commerce to create a National Competitiveness Strategy. However, I was disappointed by the way the process played out. I did not feel like the report did enough to concisely and effectively establish solutions for key issues like infrastructure investment, immigration policy, research and development funding, and others.

Question 4a. In your opinion, what targeted investment in R&D would do the most to help America stay ahead of our global competition?

Question 4b. What recent investments in R&D have had the most potential impact to American global competitiveness?

Answer. In answer to both a) and b), I believe that the most important and strategic investment that the Federal Government can make in research and development is in basic science funding—discovery science; science with no obvious commercial application. As articulated in the National Academies' Gathering Storm Report, and as reflected in the goals and objectives of the COMPETES Act, basic science drives not only real technological advancement, but also seeds progress in the development of solutions and speeds delivery of technologies to society across a broad range of industries and technical areas. Basic scientific discoveries, funded by Federal agencies, have led to commercial breakthroughs in the application of nanotechnology, biology for energy and environmental solutions, and Nobel Prizes. We don't know from where the next "solution" or "technology" may come. But, we do not that it will not come at all without basic science discoveries.

Response to Written Question Submitted by Hon. Deb Fischer to Dr. Saul Perlmutter

Question. Economic growth and job creation are critical to any state. I am quite proud of Nebraska's recent success in this area with one of the lowest unemployment rates in the country, many good jobs, and successful businesses. What do you see as the underpinnings for a vibrant economy and jobs in the future? How can this legislation [America COMPETES] contribute to that?

Answer. As my testimony indicated, it appears that the economic health of today stems from past investments in education and in research. Surprisingly enough, basic science has proven a crucial part of this mix—not just applied research that may appear the most obvious contributor. Therefore, legislation like the America COMPETES Act is vital to economic growth and for job creation throughout the United States. By authorizing increases in the levels of Federal investment in science, including basic research, the COMPETES Act would ensure that the United States remains a leader in scientific productivity and has a strong innovation and economic foundation. I am particularly pleased that the COMPETES Act contains increased funding authorization for the Department of Energy's Office of Science—a organization that is an important part of the Nation's innovation ecosystem.

Response to Written Questions Submitted by Hon. John D. Rockefeller IV to Dr. Maria M. Klawe

Question 1. According to a recent survey of scientists performed by the American Society for Biochemistry and Molecular Biology, 53 percent of respondents have turned away promising researchers due to a lack of funding and 18 percent are considering moving their research outside of the United States. Last year, a CEO of a major U.S. corporation was quoted as saying that his company was expanding abroad due, in part, to the "moribund interest in science in the U.S."

How would you describe the long-term effects of lower funding in terms of training the scientific workforce, attracting and keeping top talent, and supporting innovation and have you started to see these effects already?

Answer. When students, both undergraduate and graduate, and post-docs see their faculty having serious difficulty in finding funding to support their research, it discourages them from pursuing academic and research careers in the United States. I am already seeing a decrease in top U.S. undergraduate students choosing to enter Ph.D. programs and an increase in top U.S. Ph.D. and post-docs looking for academic and research positions in other countries.

Question 2. What changes to the education system might be necessary to ensure that U.S. companies can access a healthy, U.S.-based STEM workforce?

Answer. The key changes that are needed are:

- Improving recruitment and retention in STEM degree programs especially for women and under-represented minorities in areas like computer science and some areas of engineering where participation and retention rates are particularly low. Strategies that have been demonstrated to be highly effective in doing this include:
  - Making introductory courses relevant, interesting and non-intimidating though inclusion of applications and providing appropriate support for less well-prepared students;
  - Providing early (within the first two undergraduate years) team-based hands-on experiences via projects or research;
  - Providing exposure to role-models from industry who can demonstrate the career opportunities for graduates in various disciplines;
  - Hiring more diverse faculty (women, minorities, and people with industry experience); and
  - Placing equal emphasis on excellence in teaching as on excellence in research for promotion, tenure and salary increases.
- Federal funding via NSF and other agencies can play a huge role in driving these changes through:
  - Funding for development and dissemination of more effective introductory courses;
  - Funding for early research experiences for undergraduates as well as for more senior undergraduates;

- ◦ Funding for regional and national workshops and conferences that bring students and faculty together with industry professionals at all levels (*e.g.,* the Grace Hopper Celebration of Women in Computing, The Society of Women Engineers (SWE), etc.);
- ◦ Programs that provide funding for salary and start-up research costs for faculty that diversify a department; and
- ◦ Programs that provide significant funding for curriculum development and research to assistant and associate professors who are stars in both teaching and research (like the NSF Career Awards but with more emphasis on teaching).

Question 3. Some have argued that the United States should focus its R&D efforts more on applied research and less on basic research, as some other countries have done.

Dr. Klawe, what would a reduction in basic research funding mean for universities?

Answer. Reducing funding for basic research in U.S. universities would significantly impact innovation in the U.S. economy. The U.S. leads the world in innovation, and, to a certain extent, other countries are able to draft behind us by focusing their research investments on applications resulting from our discoveries. By leading the world in basic research, we get a head start on commercializing applications from fundamental discoveries. This is why China is making significant investments in building basic research at their top universities.

RESPONSE TO WRITTEN QUESTION SUBMITTED BY HON. AMY KLOBUCHAR TO DR. MARIA M. KLAWE

Question. Dr. Klawe, you spoke about computer programming languages and making them more accessible by helping students and the public understand programming and options for learning that may be useful to securing a career in computer science. I understand there are multiple programming languages—can you discuss these and how educators and industries can help make computer science studies more accessible and understood?

Answer. Different programming languages have different purposes. Some are easier to learn and/or use, but either run more slowly or can only be used to create a limited range of kinds of software. For example there are visual programming languages like Scratch and Alice whose purpose is to make it easy for new learners, especially younger students, to build simple programs and understand their structure, but no one would try to build anything complicated with them. A visual language allows students to assemble virtual building blocks to make a program that accomplishes the desired task. Examples of this approach can be seen on the *code.org* website.

Most languages used for serious software development are text-based, where programmers type a list of instructions for the computer to execute. For example, Python is a language that is easy to learn and can be used to easily build almost anything, but it runs too slowly for some kinds of commercial applications. Languages like C, C++, and Java are general-purpose languages designed for building large software systems that run very efficiently but are harder to learn and use. In addition there are languages that are designed to make it easier to prove that a program runs correctly or to facilitate a particular approach to programming or to build a particular kind of software system like a database. Professional software developers will often build the first version of a new piece of software using a good prototyping language like Python, and then rewrite the pieces of code that need to run more quickly in a language like C++ or Java.

Our understanding of how best to teach computer science has evolved quite a bit over the last three decades. As in some other disciplines there are differences of opinion on the best approach, but there is growing support for the following strategy. For elementary, middle school or early high school students, start by teaching some central concepts and have students understand them by solving puzzles using a visual language. For older students with more mathematics knowledge (high school juniors and seniors, college students), teach a broader set of core concepts by having students solve interesting applied problems using an easy to learn, text-based language such as Python. There are several reasons why Python is increasingly popular as an introductory text-based language for students to learn. First, it's easy. Second, because it's used by many professional software developers, knowledge of Python helps students to get a summer job. Last but not least, the transition from Python to languages like C++ or Java is much easier than from a visual language.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MARK WARNER TO DR. MARIA M. KLAWE

Question 1. More than half of all basic research in the United States is funded by the Federal Government—American universities and colleges are responsible for 53 percent of this research. I believe that we should be doing more to commercialize federally funded research, where possible. However, there is a disparity between the amount of commercialization coming from top tier research schools versus lower performing schools. A recent report from the President's Council of Advisors on Science and Technology (PCAST) found that top tier schools tend to do very well in terms of funding, while lower performing schools are more constrained in their ability to commercialize their research.

One problem I have noticed is that there are a series of closed markets in terms of who controls intellectual property (IP) within universities. Bob Litan, an innovation expert, was recently quoted in Forbes noting that "one of the big disadvantages of the traditional TLO model is that the TLO exerts the entire control over which innovations reach the market, in what form, and how fast."

Another issue is that some schools have surpassed others in terms of the amount of technology they are able to commercialize. One example is the Massachusetts Institute of Technology's Deshpande Center, which has funded 100 projects totaling over $13 million. The Center has also seen the creation of 28 spinout companies that have raised over $400 million in capital.

I have worked with Senator Moran on a proposal to accelerate commercialization within underperforming university tech transfer offices as a part of the Startup Act.

What is the most aggressive thing that we can do to spur more commercialization similar to what has been happening at schools like MIT?

Additionally, do you think that crowdfunding has any role in tech transfer? I was interested to learn that the University of Utah has recently launched its "Technology Commercialization Office" which uses crowdfunding as an alternative to traditional university "technology licensing offices" (TLOs). What do you think about this?

Answer. In my experience the faculty and student culture around commercialization is as important as the TLO in achieving great commercialization outcomes. Institutions that support and reward faculty and students who commercialize their inventions end up with a lot more patents, licenses and spin-off companies than those that don't. Some factors that positively influence the culture include:

- Facilitating leaves for faculty and students who are creating spin-off companies;
- Creating commercialization and entrepreneurship courses for undergraduate and graduate students so they can learn the process of getting patents, writing business plans, and getting angel and VC funding;
- Holding commercialization and business plan competitions to get angel funding;
- Giving faculty and students more control of the IP, especially when the work results from research primarily funded from non-institutional funds (*e.g.,* NSF or other government agencies).

For smaller universities and colleges, approaches like the Philadelphia Science Center that provide TLO services for many institutions make a lot of sense. It's important to make sure that there are not barriers in access to funding programs for multi-institutional TLO operations.

Crowdfunding for tech transfer makes lots of sense. It's what many start-ups are doing these days in any case, and it should be possible to make the model work for tech transfer as well.

Question 2. According to a 2007 report by the National Academies, faculty working on Federally funded research spend 42 percent of their time on administrative duties, such as compliance with Federal regulations. Additionally, a November 2012 PCAST report states:

> "Over the last two decades, the Government has added a steady stream of new compliance and reporting requirements, many of which vastly increase the flow of paper without causing any improvements in actual performance. Sometimes these requirements stand in the way of performance improvements."

Some solutions proposed include eliminating overly burdensome regulations, such as effort reporting, harmonizing regulation across agencies, focusing regulations on performance rather than process, as well as others.

What actions should be taken to make University research regulations more efficient, while still maintaining a high level of accountability?

Do you have any specific examples of burdensome regulations that should be reformed?

Answer. It should be possible to significantly streamline the reporting obligations without reducing accountability, but even as, or more, importantly, the amount of time that faculty spend in writing grant applications needs to be reduced. My experience is that faculty spend much more time working on grant applications than on reporting. This is partly due to the length and complexity of grant proposals and partly because of the low percentage of applications being funded.

My recommendation is to focus on improving the grant application and awarding process.

Question 3. I am very supportive of efforts to consolidate STEM programs and funding streams. President Obama's 2014 budget decreases the number of STEM programs by 50 percent, from 226 to 112. I know that some Members have expressed concerns about this consolidation, but I believe this a great way to reduce administrative overhead and to get more funding to students.

In considering the reauthorization of COMPETES, do you have any recommendations for further consolidation of STEM programs?

Answer. Unfortunately I don't know enough about this issue to make a responsible recommendation.

Question 4. I believe that America is lacking a long-term vision for economic growth and international competitiveness. There has not been enough of an effort to come together across government sectors and devise a strategy for going forward.

I included an amendment in the 2010 COMPETES reauthorization that directed the Department of Commerce to create a National Competitiveness Strategy. However, I was disappointed by the way the process played out. I did not feel like the report did enough to concisely and effectively establish solutions for key issues like infrastructure investment, immigration policy, research and development funding, and others.

In your opinion, what targeted investment in R&D would do the most to help America stay ahead of our global competition?

What recent investments in R&D have had the most potential impact to American global competitiveness?

Answer. In my opinion, the biggest economic opportunities will come from increased investment at the interface between computer science and electrical engineering and other disciplines such as medicine (and healthcare), statistics, economics, education, environment, and entertainment. The impact of advances in data analysis, sensors, and other areas of software and hardware, on all sectors of the economy is just beginning. This interface is what is driving competitiveness around the world, and we need to be at the forefront.

The most important investment in terms of actual impact over the last decade has been in information technology research, plus the networking infrastructure. The investment in genomics and proteomics also has great potential impact, as does the investment in nanotechnology.

RESPONSE TO WRITTEN QUESTION SUBMITTED BY HON. DEB FISCHER TO DR. MARIA M. KLAWE

Question. Economic growth and job creation are critical to any state. I am quite proud of Nebraska's recent success in this area with one of the lowest unemployment rates in the country, many good jobs, and successful businesses. What do you see as the underpinnings for a vibrant economy and jobs in the future? How can this legislation contribute to that?

Answer. Innovation and new technology underpin a vibrant economy, accompanied by a strong, well-educated, entrepreneurial STEM workforce.

The foundation for innovation is basic scientific research, and government funding such as the COMPETES Act plays a central role in supporting this research. Government support keeps the U.S. in the lead in terms of innovation and its commercialization.

Government funding also plays a vital role in educating the scientific workforce. COMPETES supports STEM education, especially efforts to improve STEM education and grow and diversify the STEM workforce—critical for meeting the needs of industry and spurring economic growth.

Computing has become the universal underpinning of scientific advancement and economic activity; there is incredible economic opportunity at the interface between computer science and virtually every discipline, especially the life sciences and engineering, but nearly every field is starting to advance rapidly by incorporating computer science. The U.S. needs to lead in the R&D at this interface, and in its application and commercialization, to maintain a robust, competitive economy.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. JOHN D. ROCKEFELLER IV TO DR. STEPHEN S. TANG

Question 1. According to a recent survey of scientists performed by the American Society for Biochemistry and Molecular Biology, 53 percent of respondents have turned away promising researchers due to a lack of funding and 18 percent are considering moving their research outside of the United States. Last year, a CEO of a major U.S. corporation was quoted as saying that his company was expanding abroad due, in part, to the "moribund interest in science in the U.S."

How would you describe the long-term effects of lower funding in terms of training the scientific workforce, attracting and keeping top talent, and supporting innovation and have you started to see these effects already?

Answer. There is no doubt that in order to attract top talent and ensure that our country remains a leader in innovation, the Federal Government must prioritize investment in research activities. The economic downturn disrupted traditional financing channels for budding entrepreneurs. Since 2000, our country as a whole has seen a decline in commercialization of research. At a time when private capital is most limited, it is even more important that the government provide support for innovation and economic growth.

At the Science Center, we have witnessed a greater need for Federal investment for basic and applied research. While we strongly believe in public-private partnerships, often the private sector funds only the least risky and most lucrative endeavors. Federal resources are necessary to ensure that innovators apply their knowledge and expertise widely and respond to market forces.

Question 2. Dr. Tang, drawing on your corporate experience, how does the availability of quality STEM graduates and promising researchers affect corporate decisions about where to conduct research and where to manufacture goods?

Answer. Corporate leaders understand the necessity of employing a skilled workforce to achieve success. Tech-based entrepreneurs and innovators depend on STEM talent to achieve their goals. While STEM is a growing field in this country, the demand for individuals specializing in science and math still outpaces the demand. Often in an attempt to capture these talents, corporate entities establish a presence within areas highly concentrated with STEM professionals.

At the Science Center, we witnessed this in late 2010, when Eli Lilly acquired Avid Radiopharmaceuticals, a startup company located on our campus. The Greater Philadelphia region is home to a number of leading research institutions which have spun out a number of startup companies that have attracted interest from Lilly and other large firms. Business, industry and venture capital firms will relocate to areas where talent is dense and resources are rich. STEM professionals are the backbone to innovation and as a country we must encourage top talents to embrace this field.

Question 3. Some have argued that the United States should focus its R&D efforts more on applied research and less on basic research, as some other countries have done.

Dr. Tang, if the Federal Government significantly cut back its investment in basic research, could the Nation depend on the private sector to close the funding gap or is government-industry collaboration necessary?

Answer. If the Federal Government significantly cut back its investment in basic research, I do not believe that the private sector would close the funding gap entirely on its own. As noted in the Department of Commerce's study of the Nation's economic competitiveness and innovation capacity, issued in January 2012 pursuant to the last reauthorization of America COMPETES, the Federal Government is the logical primary funder of basic research because the knowledge generated by basic research is considered to be a "public good":

A public good has two main characteristics: (1) one person's consumption of that good does not reduce the amount available for others to consume and (2) it is difficult to exclude others from consuming the good . . .

What this means, particularly for basic research, is that it may not be possible for those conducting the research to fully appreciate the benefits from research and innovation. In such cases, the social benefits (those that accrue to society as a whole) from these innovative activities likely exceed the private benefits (those that accrue just to the entity conducting the research). . . . Because individual researchers cannot recoup the full value of their work, the incentive to produce a socially optimal amount of innovative activity is lacking. This creates a potential role for government to fund innovative activity to raise this activity closer to the social optimum.

The Competitiveness and Innovative Capacity of the United States, prepared by the U.S. Department of Commerce in consultation with the National Economic Council, January 2012, pp. 3–2—3–3. (I had the privilege of serving on the 15-member Innovation Advisory Board, appointed by the Secretary of Commerce, which provided advice with respect to the conduct of the study.)

Accordingly, I believe it is critical that the Federal Government, at a minimum, maintain its level of investment in basic research so that the United States can maintain its position as a world leader in innovation. However, government-industry collaboration should continue to be encouraged, where feasible or appropriate, with respect to both basic and applied research. As noted in the Department of Commerce report, "Federal funding, coupled with private industry funding, was critical for the development of the transistor by Bell Labs in the 1950s, the growth of the semiconductor industry, and the birth of Silicon Valley in the 1980s." *The Competitiveness and Innovative Capacity of the United States,* p. 3–7. In addition, simplifying and extending the corporate R&D tax credit would encourage private industry to undertake the risks associated with R&D activity and spending.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MARK WARNER TO DR. STEPHEN S. TANG

Question 1. More than half of all basic research in the United States is funded by the Federal Government—American universities and colleges are responsible for 53 percent of this research. I believe that we should be doing more to commercialize federally funded research, where possible. However, there is a disparity between the amount of commercialization coming from top tier research schools versus lower performing schools. A recent report from the President's Council of Advisors on Science and Technology (PCAST) found that top tier schools tend to do very well in terms of funding, while lower performing schools are more constrained in their ability to commercialize their research.

One problem I have noticed is that there are a series of closed markets in terms of who controls intellectual property (IP) within universities. Bob Litan, an innovation expert, was recently quoted in Forbes noting that "one of the big disadvantages of the traditional TLO model is that the TLO exerts the entire control over which innovations reach the market, in what form, and how fast."

Another issue is that some schools have surpassed others in terms of the amount of technology they are able to commercialize. One example is the Massachusetts Institute of Technology's Deshpande Center, which has funded 100 projects totaling over $13 million. The Center has also seen the creation of 28 spinout companies that have raised over $400 million in capital.

I have worked with Senator Moran on a proposal to accelerate commercialization within underperforming university tech transfer offices as a part of the Startup Act.

What is the most aggressive thing that we can do to spur more commercialization similar to what has been happening at schools like MIT?

Additionally, do you think that crowdfunding has any role in tech transfer? I was interested to learn that the University of Utah has recently launched its "Technology Commercialization Office" which uses crowdfunding as an alternative to traditional university "technology licensing offices" (TLOs). What do you think about this?

Answer. I am aware of the provision to which you are referring to in your legislation, the StartUp Act. We at the Science Center are highly supportive of this effort and applaud your attention to the need for a Federal commitment to commercialization.

I believe that this specific provision could be further strengthened by allowing eligible non-profit venture development organizations (VDOs) to assist universities with commercialization activities. As you mention, some universities and research institutions are more adept at tech transfer than others. There are VDOs across the country, including research parks and other technology-based economic development organizations, which have extensive experience with evaluating commercialization potential and market viability. I urge you to allow universities the ability to contract with VDOs like the Science Center to provide proof-of-concept and other commercial research. Often these entities match resources and leverage additional funding, to enable a TLO to be able to do more than it could on its own.

An example of this is the Science Center's QED Proof-of-Concept Program. While QED was modeled after MIT's Deshpande Center, our program is unique in that it is multi-institutional, and currently counts 21 colleges, universities, hospitals and research institutions in the Greater Philadelphia area as participants. All of these institutions have agreed to common terms and conditions of participation.

When we started QED, our premise was that given access to appropriate funding, business advice and other resources, participating institutions that have not previously taken a lead in commercialization would have marketable technologies. After five years of running the program, we have found this premise to be true. While many of the winners do come from institutions like the University of Pennsylvania and Drexel University, we have also funded projects from Philadelphia University, the University of Delaware, Lehigh University and Rutgers University. The QED program has resulted in six licenses and $9 million in follow on capital to date. We strongly believe this multi-institutional model could be replicated across the country, in virtually any R&D domain.

Crowdfunding could be an important tool in the toolbox of entrepreneurs interested in commercialization of technology. As has been mentioned, the private markets only invest in low-risk, high-yield projects. Crowdfunding could provide access to capital for technologies or therapies with market potential.

That said, it is imperative that safeguards be put in place to ensure that individuals who can participate in crowdfunding arrangements meet certain criteria and agree to specific terms of return on investment. Fraud prevention measure must also be put into place by the Federal Government to protect investors.

Question 2. According to a 2007 report by the National Academies, faculty working on Federally funded research spend 42 percent of their time on administrative duties, such as compliance with Federal regulations. Additionally, a November 2012 PCAST report states:

"Over the last two decades, the Government has added a steady stream of new compliance and reporting requirements, many of which vastly increase the flow of paper without causing any improvements in actual performance. Sometimes these requirements stand in the way of performance improvements."

Some solutions proposed include eliminating overly burdensome regulations, such as effort reporting, harmonizing regulation across agencies, focusing regulations on performance rather than process, as well as others.

What actions should be taken to make University research regulations more efficient, while still maintaining a high level of accountability?

Do you have any specific examples of burdensome regulations that should be reformed?

Answer. Redundant and overly burdensome regulations impact not only universities but the productivity of their researchers. Some of our university partners have mentioned that regulations related to conflict of interest can often discourage research faculty from working with industry. We at the Science Center believe that university/industry partnership can spur commercialization and job creation, and therefore would support efforts to modify the regulations so as to encourage faculty to work with industry.

The corporate tax rate of 35 percent in this country provides a competitive advantage for other countries to house our talent and capital. We lose American educated researchers abroad due to antiquated immigration laws as well as uncompetitive tax policy. I would support repatriation incentives for U.S. companies to move operations back onshore in an effort to retain both talent and economic growth.

Question 3. I am very supportive of efforts to consolidate STEM programs and funding streams. President Obama's 2014 budget decreases the number of STEM programs by 50 percent, from 226 to 112. I know that some Members have expressed concerns about this consolidation, but I believe this a great way to reduce administrative overhead and to get more funding to students.

In considering the reauthorization of COMPETES, do you have any recommendations for further consolidation of STEM programs?

Answer. In general I am supportive of coordinating programs with similar or dual missions to maximize resources and reduce redundancy. I understand that when programs are consolidated there are always concerns that the specific focus of each program will diminish. As long as we continue to prioritize STEM education, I support providing one entity (the NSF) with resources to improve inter-agency collaboration and promote a nationwide STEM agenda.

Question 4. I believe that America is lacking a long-term vision for economic growth and international competitiveness. There has not been enough of an effort to come together across government sectors and devise a strategy for going forward.

I included an amendment in the 2010 COMPETES reauthorization that directed the Department of Commerce to create a National Competitiveness Strategy. However, I was disappointed by the way the process played out. I did not feel like the report did enough to concisely and effectively establish solutions for key issues like infrastructure investment, immigration policy, research and development funding, and others.

In your opinion, what targeted investment in R&D would do the most to help America stay ahead of our global competition?

What recent investments in R&D have had the most potential impact to American global competitiveness?

Answer. As a member of the Innovation Advisory Board that drafted the report on U.S. competitiveness and innovative capacity, I also had hoped for a more comprehensive document.

Related to your question about R&D priorities, I strongly believe the Federal Government must invest more in applied research, as a complement to the Nation's continued support of basic research. To be clear, I do not advocate for commercialization at the expense of basic research; however, we must empower researchers to study proof-of-concept and think about market viability. In large part, a shift in culture at many universities must occur to create environments that support commercialization activities, and a commitment from the Federal Government could help spur this change.

I would argue that Federal investment in human capital through STEM education is the most significant in terms of potential for American global competitiveness. There is no one technology or therapy that makes America competitive alone; rather, it is our talented researchers that are continually investigating, finding new products and creating new companies. Significant and important technologies have been developed with the assistance of Federal funds in the fields of life sciences, national defense, and space exploration, all of which make our country competitive among nations. Without a talented and education workforce these developments would never come about.

RESPONSE TO WRITTEN QUESTION SUBMITTED BY HON. DEB FISCHER TO DR. STEPHEN S. TANG

Question. Economic growth and job creation are critical to any state. I am quite proud of Nebraska's recent success in this area with one of the lowest unemployment rates in the country, many good jobs, and successful businesses. What do you see as the underpinnings for a vibrant economy and jobs in the future? How can this legislation contribute to that?

Answer. Regional economies must recognize their strengths and build an environment where all necessary economic components can work together and collaborate. In Philadelphia we are fortunate to have a large concentration of life sciences resources, leading research institutions and industry, in close proximity. For regional economies to prosper, essential components—such as investors, inventors and entrepreneurs—should be given the space, opportunity and incentive to collaborate on a regular basis.

In particular, I am a strong proponent of "scalable innovation," in which regional economies assess their innovation capacity in conjunction with their particular assets and strengths, and then scale in accordance with local market forces. While Southeastern Pennsylvania, for example, is focused on an innovation economy that highlights the life sciences, other areas could "scale" innovation in manufacturing, energy or other industries in which they have strength.

The Federal government should support local, regional and state efforts to create innovative and vibrant economies. The America COMPETES Act is an important tool that reinforces this commitment. At the Science Center, and at other technology-based economic development entities across the nation, we work to commercialize federally funded research; that is, to transform the significant investment the government has made in basic research into marketable technologies and companies. America COMPETES's creation of the Office of Innovation and Entrepreneurship at the Department of Commerce has spurred a focus on and investment in translational research and commercialization. The Regional Innovation Program will assist local economies in scaling to their innovation potential. Finally, the reauthorization of America COMPETES provides us with the opportunity to further capitalize on promising research and allow for a focus on job creation. With additional tools, such as the ability to compete directly for a larger number of National Science Foundation grants, non-profit economic development entities across the Nation could significantly boost their efforts to assist academic researchers and start-up entrepreneurs, thereby leading to more economic development and job creation.

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