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LEVERAGING THE U.S. SCIENCE AND TECHNOLOGY ENTERPRISE

HEARING

BEFORE THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION UNITED STATES SENATE

ONE HUNDRED FOURTEENTH CONGRESS

SECOND SESSION

MAY 11, 2016

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SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

ONE HUNDRED FOURTEENTH CONGRESS

SECOND SESSION

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LEVERAGING THE U.S. SCIENCE AND TECHNOLOGY ENTERPRISE

WEDNESDAY, MAY 11, 2016

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

The Committee met, pursuant to notice, at 10 a.m., in room SR–253, Russell Senate Office Building, Hon. John Thune, Chairman of the Committee, presiding.

Present: Senators Thune [presiding], Blunt, Moran, Johnson, Heller, Gardner, Klobuchar, Markey, Booker, Udall, and Peters.

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

The CHAIRMAN. Good morning. This hearing will now get underway.

I want to welcome our witnesses to today's hearing, which presents a good opportunity to discuss ways to improve the efforts of the Federal Government, the private sector, and academia in R&D, STEM education initiatives, and technology transfer of scientific research to commercial applications.

The Committee has jurisdiction over important Federal science agencies, including the National Science Foundation, or NSF, the National Institute of Standards and Technology, or NIST, and the White House Office of Science and Technology Policy, or OSTP. And the Committee's been actively developing legislative proposals to confront the challenges associated with advancing the U.S. science and technology enterprise in our budget environment.

The good news is that, among individual countries, the United States is still the largest investor in public and private R&D, comprising 27 percent of the global R&D total in 2013, according to the National Science Board. But, China's catching up, with 20 percent of the global total.

While we could hope for more resources, tough budget realities underscore the importance of developing policy solutions that maximize our Federal investment so we can stay competitive, get the biggest bang for our buck, and leverage even more private-sector resources to expand the reach of our R&D. This committee has been active on this front.

Last year, in consultation with Ranking Member Nelson, we established an Innovation and Competitiveness Working Group of the Commerce Committee to inform efforts to craft legislation to reauthorize science and technology R&D policies previously directed under the America COMPETES Act. We asked Senators Gardner

and Peters to lead this Working Group, and we're appreciative of their sustained efforts over many months to help develop consensus-based policy solutions that could comprise a bipartisan Commerce Committee product.

The Working Group convened a series of candid bipartisan discussions to gather input from the U.S. science and research community regarding Federal R&D policy priorities. The roundtable format of these meetings allowed for a free-flowing discussion among key stakeholders. These roundtable meetings focused on the topics of maximizing the impact of basic research, STEM education and workforce issues, and research, commercialization, and technology transfer. We had broad participation by research universities, government advisory bodies, and nonprofit research organizations in the informal discussions with Senators. Members of the public and interested groups were also invited and encouraged to submit input on the topics via e-mail, with over 250 e-mail submissions received on these three topics.

Common themes arising from the roundtables included support for continued investment by the Federal Government in basic research, as well as encouragement of wider participation in STEM subjects, stronger partnerships among government, the private sector, and academia that could better leverage discoveries emerging from our research universities to drive innovation, and the importance of minimizing barriers and improving incentives for universities in the private sector to better maximize the scientific and economic return on limited Federal research resources.

The Committee's Working Group is developing bipartisan legislation drawing on the input received from the roundtables and stakeholder feedback, related bills introduced by members of the Commerce Committee and others, and policy recommendations made by entities such as the American Academy of Arts and Sciences, the Information Technology Innovation Foundation, and the National Academy of Sciences. We are hopeful the bill will be ready in the coming days.

Again, I want to thank the witnesses for being here today, and I look forward to hearing about policy ideas that can leverage our science and technology enterprise, such as improved public-private partnerships, reduction of administrative burdens, and improved strategic planning of the Federal R&D investment.

We have a distinguished list of witnesses from academia, the private sector, and government advisory bodies testifying before the Committee today. Dr. Droegemeier joins us having just finished his term as Vice Chair of the National Science Board this past Friday. Dr. Wing has served as Corporate Vice President for Microsoft Research, as well as at NSF, and contributed to a recent report published by the American Academy of Arts and Sciences entitled "Restoring the Foundation." Dr. Atkinson's organization, ITIF, has published numerous recommendations related to tech policy. And both he and Dr. Droegemeier previously participated in our Working Group roundtables on STEM and commercialization. Finally, Dr. Munson joins us from the University of Michigan's College of Engineering, where he's helped translate university research into commercial applications, including at his own company, InstaRecon.

I want to welcome our distinguished panel today, and thank you so much for being here.

And we'll now flip it to our Ranking Member, Senator Peters, for an opening statement.

STATEMENT OF HON. GARY PETERS,
U.S. SENATOR FROM MICHIGAN

Senator PETERS. Thank you, Chairman Thune. And thank you for the Committee's focus on this very important issue of U.S. research enterprise.

I'd also like to thank all the witnesses for taking the time to share their expertise with us today. And I'd especially like to welcome Dr. David Munson, the Dean of Engineering at the University of Michigan.

Like many of you, I grew up during the Apollo era inspired by Neil Armstrong's first steps on the Moon and mesmerized by the launch of the 36-story-tall Saturn V rocket that took him and others to the Moon. But, the impacts of the space program reached beyond inspiration to growing the economy and improving the security of our Nation. In fact, as much as half of the economic growth in the United States over the last 50 years is attributable to advances in science and technology. These innovations led to the founding of global companies and establishing the United States as the international leader in innovation.

But today, the picture is troubling. The United States is quickly losing ground in the global marketplace. We are spending less on science, research, and education, while our competitors are spending more. Over the last year, I was honored to join my colleague, Senator Cory Gardner, in examining the issues of American competitiveness and policy solutions to reassert America's place internationally. As mentioned by Chairman Thune, we held three roundtables on innovation and competitiveness. These forums examined a variety of topics centered around the role of Federal R&D, building a STEM workforce, and improving commercialization of federally-funded research.

The Working Group received hundreds of inputs from industry, academia, science organizations, and economic development organizations on policies to improve the American innovation ecosystem. Experts from the scientific community, industry, academia, nonprofits, and economic development organizations all agree that modest, sustained, and predictable increases in Federal research and development investments are critical to ensuring the economic competitiveness of the United States moving forward. The community voiced support for continued investment by the Federal Government in basic research while providing opportunities to commercialize that research, where appropriate. We heard that the United States must improve participation in STEM among women and underrepresented minorities. These groups represented the largest untapped talent pool to fulfill the shortage of qualified STEM workers.

We also heard that reducing administrative burdens on researchers could significantly increase the scientific and economic return on Federal research investment. Some expressed that stronger partnerships are needed among government, the private sector,

and academia in order to better capitalize on discoveries emerging from our research universities.

Coming from the great State of Michigan, that's a need that really resonates, certainly with me. And I firmly believe that, if we want to continue to be a leader in the global economy, we need to make things. That's something we do pretty well in Michigan. We make things. From large manufacturers to small mom-and-pop businesses, the amazing industrial base that once dominated the global auto industry is now being retooled into advanced technologies to build things like space vehicles and renewable energy systems. We need to double down on that type of transformation here in the United States.

We also have some of the world's greatest research universities in Michigan. These universities and others all across the Nation are investing in and developing the next-generation technologies that will keep America relevant in the global marketplace. Investments in advanced manufacturing, for example, will lift all ships, creating new capabilities that can increase commercial productivity.

Simply put, science and technology are critical to American competitiveness, and we need to focus on the entire ecosystem, from STEM or STEAM to basic research, to application and commercialization, to the inspiration that results from ambitious endeavors, like exploring space and other frontiers of science. That whole ecosystem of discovery and innovation is absolutely critical to American competitiveness. These are big challenges that require everyone, Democrats and Republicans, the Federal Government, and State and local governments, industry, and academia to work together on these solutions.

The discussion today will continue to inform that legislation, and I look forward to the input of the witnesses. Thank you again for being here.

The CHAIRMAN. Thank you, Senator Peters. And thanks again to you and Senator Gardner for your great work on the Working Group and what that has led to. And, like I said, I hope we'll have a bill here before long that we can start to show people.

Well, we'll start with our panel. I think we have a vote at 10:30. I'll try and get through all the testimony and then perhaps get into a few questions before the vote, and try and keep rolling through the vote, if that works. And if the witnesses could confine their testimonies as closely as possible to 5 minutes, that would be most helpful.

So, Dr. Droegemeier, we'll begin with you. Thank you.

STATEMENT OF DR. KELVIN DROEGEMEIER, IMMEDIATE PAST VICE CHAIR, NATIONAL SCIENCE BOARD

Dr. DROEGEMEIER. Thank you very much, Chairman Thune, Ranking Member Nelson—I appreciate your good work—and Senators Peters and Gardner, members of the Committee.

I am Kelvin Droegemeier, Vice President for Research at the University of Oklahoma, and, as you heard, immediate past Vice Chair of the National Science Board. Although I testify today in my capacity as a University Vice President and Professor, a lot of my

thinking is shaped by my dozen years on the National Science Board.

As you all know, we live in a time of extraordinary possibilities. The pace of discovery is accelerating. The global science and engineering ecosystem is rife with competition but also tremendous opportunities for cooperation. Domestically, we're seeing a growing demand for workers with STEM skills, including in occupations traditionally not seen as STEM jobs. We all have heard about LIGO recently, an amazing instrument that now verified Einstein's prediction of gravitational waves 100 years ago, that's completely transforming our understanding of the universe. We have the ability now to sequence a human genome in a matter of hours, as opposed to a matter of years. Technology is touching our lives every day.

And we live in this world because of our sustained Federal investments in basic research. It is absolutely the starting point for everything that follows. But, the generation who cut their teeth on the space race, as we heard from Senator Peters, they're now retiring, and we're investing less of the Federal budget in R&D than in any time since Sputnik. And, over the past decade, Federal investments in basic research have fallen over 10 percent. Yet, we have to be mindful of the realities of the budget and the challenges posed by the slow but steady growth of mandatory spending programs. And, despite those challenges, I'm very optimistic.

This committee is taking a first and very important step in making science bipartisan again, which is really boosting the morale of the scientific community. I cannot say enough good things about Senator Peters and Gardner in the listening sessions that I had the privilege to participate in. It really was a boon to our enthusiasm about research, and we're very, very excited about what's happening here today.

I want to highlight, just very briefly, three bipartisan activities that we think could help this legislation and help the U.S. retain its leadership amid very significant fiscal constraints.

The first suggestion is that the Federal Government focus on where it adds unique value, especially in basic or discovery research. It is the seed corn of our scientific enterprise. And if we eat that seed corn, and we let other countries drive the research agenda, then we will absolutely regret it in the future. And so, even in a very constrained fiscal environment that we all understand, we have to invest in all areas of basic research. If the past 65 years since the founding of the National Science Foundation has taught us anything, it's that there are no sure bets and that winners will be found where we least expect them. Today's pressing challenges are highly interdisciplinary and they're often centered on people as well. In this environment, it would be a very big mistake to exclude any discipline, especially the social, behavioral, and economic sciences.

This is true in my own field. I'm a meteorologist, and I study how we predict the weather, and especially how we predict tornados, like those that ravaged Oklahoma a couple of days ago. At the end of the day, we're dealing with human beings who make decisions. All the science and technology in the world—physical science, engineering—will not prevent lives from being lost. We

have to understand how people react to using that technology. That's in the social behavioral science domain. It involves psychology, sociology, anthropology. And we, as meteorologists, have awakened to that fact, and we're working with those disciplines.

Second, as you heard from the Chairman, we have to reduce administrative burdens and other unnecessary drains on research dollars. We have to get our scientists back to the bench and out from underneath a mountain of paperwork. Researchers are spending, on average, 42 percent of their time on administrative activities. We certainly understand and appreciate the importance of accountability and compliance. What we want to see is a removal of duplicative regulations or things that are really having no positive impact on ensuring accountability and transparency and effectiveness in research. And led by Senators Lamar Alexander and Patty Murray, the Senate HELP Committee, as you know, recently took steps to help address that problem. There's similar legislation in the House. The scientific community is very, very supportive of that, and I urge this committee to adopt those recommendations in the Academy's report on Federal research regulations.

Finally, I would ask that you look for ways to make agency budgets more predictable. That may seem strange coming from a meteorologist, but really it will help us all plan strategically and minimize costs associated with unexpected delays. We also have to think about the workforce of tomorrow, realizing STEM education investments go hand-in-hand with discovery research, training the next generation of researchers. Our Nation thrives on a STEM-capable workforce at every level, even in non-STEM jobs, and we have to make certain that all of our folks have the capabilities they need to succeed.

The new COMPETES legislation offers a really wonderful opportunity, even in constrained fiscal times, to think big. It means reinvesting in basic research in all fields across the enterprise, and also stimulating academic/industry partnerships and interagency collaborations. It means reducing administrative burdens and building on successful programs that spur commercialization such as the NSF I-Corps program.

My colleagues and I in the scientific community deeply appreciate the bipartisan effort that you all are showing, and the opportunity to testify before you today.

Thank you very much.

[The prepared statement of Dr. Droegemeier follows:]

PREPARED STATEMENT OF DR. KELVIN DROEGEMEIER, VICE PRESIDENT FOR RESEARCH, UNIVERSITY OF OKLAHOMA AND PAST VICE CHAIR, NATIONAL SCIENCE BOARD

Introduction

I thank Chairman Thune, Ranking Member Nelson, Senators Gardner and Peters, and other committee members for the opportunity to testify on the vital role of the science and engineering enterprise to 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 am also, as of yesterday, immediate past vice-chair, 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 testi-

fying today as Vice President for Research at the University of Oklahoma, although my remarks are also shaped by my dozen years on the Board.

The prospect of a new COMPETES Act comes at a time of extraordinary possibilities for science. The NSF-sponsored Laser Interferometric Gravitational Wave Observatory (LIGO) recently opened new windows on our understanding of the universe and is creating an entirely new area of research into gravitational wave astronomy. Clustered Regularly Interspaced Short Palindromic Repeat (CRISPRs) are helping us cheaply and precisely edit the human genome to find ways to prevent and cure insidious diseases such as cancer, Alzheimer's, diabetes, and HIV/AIDS. And the potential for using big data to expand the scope of our research and to revolutionize how we do science is now before us. The NSF has bold plans to lead the science enterprise to new frontiers. The Foundation envisions supporting research on how genes interact with the environment, on interactions between people and technology, and on the rapidly changing Arctic. The opportunities before us are incredible, all the more so when you think of the pace at which scientific advancement has accelerated during the past few decades and the tools and level of understanding we now have.

Science and engineering are now truly a global enterprise. Other countries have followed the U.S. lead, and are emulating our model, investing heavily in S&E research, education, and workforce development. China, for example, has nearly tripled the number of high performance computing (HPC) systems on the most recent "TOP500" list, while the number of systems in the United States has fallen to the lowest point since 1993. We know how to meet this challenge. The recent National Academies report, *Future Directions for NSF Advanced Computing Infrastructure to Support U.S. Science and Engineering* in 2017–2020, for instance, outlines a framework to ensure continued U.S. leadership. The question before the U.S. is whether we have the will to capitalize on these emerging opportunities.

Over the past decade, NSF's research budgets have been nearly flat in real dollars. The Federal Government now invests less of its budget in research and development (R&D) than at any time since Sputnik was launched. Over the longer term, this will need to change if we want to remain world leaders in S&T. In the near term, I am mindful of the enormous challenges posed by the slow-but-steady growth of mandatory spending programs. Yet despite these fiscal realities, I am also hopeful, in a way that I have not been since the National Academies undertook the *Rising Above the Gathering Storm* report and Congress responded with the original COMPETES Act. This committee has already addressed one of the greatest long-term threats to American innovation: You've made science bipartisan again, countering rhetoric that has at times made the research community feel under siege.

My testimony offers a three-pronged approach to leveraging our existing R&D resources. First, we need to focus on where the Federal Government adds unique value. This includes the basic research that is generally not conducted by the private sector. Second, we need to maximize the impact of our investments, particularly by decreasing regulatory burdens and increasing the effectiveness of commercialization activities. Finally, we need to redouble our efforts to develop the workforce of tomorrow. For decades, our country has reaped the returns on huge investments in the space race, especially in terms of our science and engineering workforce. We can only address the oncoming "silver tsunami" of retirements by leveraging the full breadth of our Nation's talent pool.

Importance of Discovery Research

In the waning days of World War II, President Roosevelt, recognizing that wartime cooperation between the Federal Government and scientific community had contributed to the U.S. victory, asked Vannevar Bush how the Government could promote scientific progress in the postwar period. That report, *Science—The Endless Frontier,* called for the creation of what would eventually become NSF. Bush stressed the essential role of the Federal Government in funding basic—or "discovery"—research and cultivating the Nation's "scientific talent."

Discovery research uses the scientific method to understand the natural universe, and it is the DNA from which new innovations emerge. That DNA, representing thousands of discoveries across all science and engineering 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 with profound benefits for society. Nowhere is this more evident than in current and rapidly evolving national security challenges. Discovery research has fueled advances in image processing, electrochemical sensing, and data mining. These advances have, in turn, led to the rapid creation of field-deployed technologies for enhancing security in airports, improved safety of our soldiers, and the ability to fight next generation cyber-attacks.

Federally-funded discovery research is just one vital component of our Nation's highly interdependent innovation ecosystem. Total national investment in R&D includes funding by the Federal Government, states, colleges and universities, and the business and nonprofit sectors. Today, businesses fund about two-thirds and perform nearly three-quarters of R&D in the United States. Because returns on investments in basic research are unpredictable and may take years, if not decades, to materialize, the business sector focuses largely on development. In 2013, businesses directed about 78 percent of their R&D resources toward development, compared to just under 16 percent toward applied research and about 7 percent towards basic research.

The Federal Government, and NSF in particular, plays a critical, complementary role by supporting discovery research. NSF's motto is "Where Discoveries Begin," and NSF is the only Federal agency whose mission is to promote the progress of discovery research in *all* fields of science and engineering. By investing in early stage research in all scientific fields, NSF lays the knowledge foundation that makes possible the application-oriented science pursued at other agencies and the technological innovations developed by the Nation's businesses. I fully agree with Senator Peters, who said "Basic R&D is the seed corn of our economy, and the innovation that it generates helps build new industries, increase productivity, and enhance American competitiveness."

NSF-funded research not only helps our Nation tackle the societal challenges of today and tomorrow, but also provides the U.S. with a competitive advantage in a globally competitive marketplace. In April of this year, Bill Gates wrote that "Government funding for our world-class research institutions produces the new technologies that American entrepreneurs take to market." Recognizing this, numerous developed and emerging economies, including South Korea, India, Brazil, and especially China, have ramped up their investments in R&D. Indeed, China is now second in the world in R&D, having surpassed Japan and drawn equal with the European Union. While science and technology is not a zero-sum-game—innovations in China can improve the life of Americans—it is important that we remain a global leader. Continued U.S. leadership in science will ensure that future generations of Americans will live in a secure and prosperous country.

NSF's ability to invest in discovery research in all fields of science, including the social, behavioral and economic (SBE) sciences, is central to this competitive advantage. The United States is one of the only countries in the world that makes significant investment in SBE sciences. NSF-funded research into understanding individual and societal human behavior often sits at the interface between technology and the people who use it. If we do not understand why some people ignore storm warnings or the factors that support economic development or drive the activities of rogue states and terrorists, we are crippling the ability of our Country and every individual in it to reap the full benefits that scientific and technological progress has to offer.

The broader point is that the knowledge gained from discovery research in all disciplines strengthens our innovation ecosystem and ensures that the United States is maximally prepared for an unpredictable future. Because we do not know *a priori* how we will solve the great challenges of the 21st century or even what all of these challenges will be, it is imperative that we combine robust support for core research in all fields of science with interdisciplinary and collaborative initiatives. As the National Academies wrote in its 2014 report, *Convergence,* the "merging ideas, approaches, and technologies from widely diverse fields of knowledge at a high level of integration is one crucial strategy for solving complex problems and addressing complex intellectual questions underlying emerging disciplines." Said another way, some of the most societally important and intellectually challenging problems occur not within disciplines, but at the boundaries among many disciplines. I have included two examples that illustrate this point:

1. Discovery research at the interface of the biological and mathematical sciences is addressing important human health challenges. The spread of infectious diseases from wildlife to humans is on the rise, with this year's Zika virus and last year's historic Ebola outbreak as recent examples. Factors that affect such outbreaks include the density of human and wildlife populations, changes in land use, and human behavior. A joint initiative between NSF's Division of Mathematical Sciences and the National Institute of Health's National Institute of General Medical Sciences has supported work on Ebola, fostering collaborative research projects that leverage the contributions of disease ecologists, epidemiologists, mathematicians and economists to better understand this and other rapidly evolving infectious diseases.

2. Nearly a decade ago, NSF—recognizing that the electricity sector was insufficiently focused on security—invested in early stage research on how to design and build resilient cyberinfrastructure for the power grid. This research, sponsored by NSF's Computer and Information Science and Engineering (CISE) Directorate, has since been carried forward with funding from the Department of Energy's Office of Electricity Delivery and Energy Reliability (DOE–OE) and the Department of Homeland Security Science and Technology Directorate. Today, the Trustworthy Cyber Infrastructure for the Power Grid Project (TCPIG) is collaborating with national laboratories and the utility sector to improve the design, security, safety, and resiliency of the U.S. power grid. Thanks to these successive Federal investments, the group's technologies are being piloted in real utility environments and their work has become foundational technology for three start-up companies.

Our national innovation ecosystem is only as strong as its component parts. In addition to the threat posed by efforts to dramatically decrease or eliminate funding for the SBE sciences, our innovation ecosystem is equally weakened by the challenges facing our Nation's colleges and universities. The majority of NSF-funded discovery research is performed by universities and colleges, and these institutions are equally important in educating and training the next generation of STEM-capable workers. The NSB's recent policy-focused Companion Brief to *Science and Engineering Indicators 2016* entitled, *Higher Education as a Public and Private Good,* describes how declines in Federal support for R&D, waning state funding for public research universities, and tuition increases are converging to create a "perfect storm." This storm threatens to undermine the ability of these institutions to perform their vital research and education missions.

Reduce administrative burdens and other drains on research dollars

The current funding challenges only serve to underscore that we must ensure that taxpayer dollars are spent wisely and efficiently. NSF ensures that it invests in only the best scientific projects using two evaluation criteria—*intellectual merit* and *broader impacts.* NSF's merit review process is highly emulated and widely considered the best in the world. Despite the impressive track record of discoveries produced by NSF's merit review system, NSF and the NSB regularly strengthen and clarify it. For example, in 2011 the NSB re-examined the intellectual merit and broader impacts criteria,[1] and in 2013 NSF launched the *Transparency and Accountability Initiative* to strengthen Agency efforts in transparency and accountability around the merit review process, and the Board adopted a formal policy resolution in May of 2015.[2]

While transparent, merit-based competition is a powerful incentive toward the efficient use of taxpayer dollars, it is not enough by itself. At a time of fiscal challenges and with low funding rates at many Federal agencies, we also need to ensure that Federal dollars are spent efficiently, without fraud, abuse, or waste. This includes reducing the administrative workload placed on federally-funded researchers at U.S. institutions. As detailed in the Board's 2014 report and the subsequent National Academies' report, there are numerous opportunities to address unnecessary regulations that interfere with the conduct of science in a form and to an extent substantially out of proportion to the well-justified need to ensure accountability, transparency and safety.

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. 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.

I am heartened by the attention this committee and others in Congress have paid to these studies and, based on legislation already introduced, I am confident that any comprehensive legislation written by this committee will address these concerns in a bipartisan way. I hope that attention will also be given to the forthcoming *Part II* report from the Academies' Committee on Federal Research Regulations and Reporting Requirements. I am also pleased to report that the NSF has been acting

[1] *http://www.nsf.gov/nsb/publications/2011/nsb1211.pdf*
[2] *http://www.nsf.gov/od/transparency/transparency.jsp*

independently to implement some of the recommendations from the Board's report. Great improvements have been made in standardizing and simplifying some of NSF's reporting requirements and in avoiding errors in grant submission. In addition, a number of pilot programs are also underway to streamline the proposal process (for instance, exploring just-in-time budget submissions).

While I am sensitive to the budget constraints faced by legislators, I feel it is incumbent on me to remind you that unpredictable funding is also a source of inefficiency. Simply put, continuing resolutions and unknown funding bring with them delays that cost money. This is especially true for NSF's Antarctic program and our large facilities. Congressional support for long-term strategic plans, including community-driven decadal surveys and prioritization processes, can help reduce uncertainty in this regard.

One of the biggest challenges facing NSF and basic research generally is the balance between high-risk, high reward research and delivering tangible returns to taxpayers. I urge the Committee to embrace the complexity of our enterprise, and to understand that these long-term basic research investments must be undertaken by the public sector. In my view, the level of oversight should be linked to the level of risk in our investments. Science should never be risk free, and oversight activities—never free—should always have a positive return on investment.

NSF is keeping this in mind as it implements the recommendations in the recent National Academy of Public Administration (NAPA) report, *National Science Foundation: Use of Cooperative Agreements to Support Large Scale Investment in Research*. This is proving a timely tool to improve NSF's oversight of large facilities. The NAPA committee rigorously addressed its charge, which was jointly developed by the NSB and NSF Senior Management, identified areas where NSF can improve, and provided recommendations that will strengthen our oversight of facilities. The Board and NSF Senior Management are in general agreement with the Panel's recommendations.

The Foundation's leadership and I appreciate Congress' shared recognition that wise stewardship of taxpayer dollars is essential to the progress of science. In that vein, I note that while the NAPA report described a need for heightened accountability, it also concluded that Cooperative Agreements (CAs) are an appropriate mechanism for NSF to use for designing, constructing, and operating large facilities. NSB endorses this conclusion and I have repeatedly seen how NSF uses these cooperative tools to address the Board's concerns.

With respect to the NAPA report, I urge the Committee to set goals and expectations while preserving an appropriate level of flexibility with respect to pre-award cost analyses, audits of incurred costs, and management fees. I believe that prohibiting the use of management fees in cooperative agreements (as allowed by OMB regulations) would ultimately result in the public paying more for less research. Even codifying current practice risks hampering opportunities for additional efficiencies. For instance, mandatory incurred cost audits for large facility construction projects can cost millions of dollars that would have otherwise gone to funding grants. It is more sensible, and appropriate, to conduct such audits only when project risk warrants it. NSF's recent improvements in large facilities management, recognized by NAPA as "tremendous efforts," have to a great extent sought to realize a risk-appropriate level of oversight.

In this vein, I especially commend the Academies' recommendation to ensure balance between Inspectors General's twin mandates. The Inspector General Act of 1978 charged leadership in preventing fraud and abuse *and* in promoting "economy, efficiency, and effectiveness in the administration of programs." I believe the associated recommendations regarding transparent reporting of costs and recoveries, interpretation of agency policies, and risk-based methodology can be helpful in ensuring balance between these mandates.

Finally, I remind the Committee that in many cases it is worth paying for transparency and oversight. Inspectors General have delivered tremendous returns to taxpayers, as have regular audits, and NSF's Large Facilities Office (LFO). NSF is already pursuing the NAPA panel recommendation that it add training for program officers and add personnel to the LFO. These improvements are necessary, but they cost money. While NSF continues to process a larger number of more complicated grants, its Agency Award Management and Operations (AOAM) account has remained flat. Even the most efficient handling of grants and oversight of projects requires resources, and I encourage the Committee to support increases to this account. Without increases, I worry that these costs could degrade or reduce NSF's investments in research and education.

STEM education and STEM-capable workforce

Investments in STEM education go hand-in-hand with investments in discovery research. Both are vital to continued U.S. scientific leadership, economic competitiveness, and national security and prosperity. Furthermore, to compete and win in the current global environment, the Nation needs flexible STEM-capable workers at every education level. The days in which STEM skills were necessary only for occupations traditionally classified as "science and engineering" (S&E) are over. We must recognize this breadth and heterogeneity of the STEM workforce within the framework of America COMPETES.

Workers who hold a STEM degree, work in a STEM job, or who use significant STEM knowledge and skills in their jobs are part of the STEM workforce. Of course, the STEM workforce includes scientists and engineers who further scientific and technological progress through research and development (R&D). In addition, workers in non-R&D jobs who use STEM knowledge and skills and those in technically demanding jobs who need STEM capabilities to accomplish occupational tasks are also part of this workforce. Far from being a monolithic, homogenous group, the STEM workforce is comprised of workers with different educational qualifications who are employed in a wide range of fields and careers. All of these jobs have one essential characteristic in common: They are the better-paying jobs that have driven recent economic growth.

In 2013, over 13 million U.S. workers were employed in an occupation classified as "S&E" or "S&E-related". Yet in a survey of individuals with at least a four-year degree, including many working in sales, marketing, and management, almost 18 million reported that their job required at least a bachelor's degree level of S&E expertise. In fact, in 2013, the number of non-S&E jobs that require a bachelor's level of S&E skills surpassed the number of traditional S&E jobs for the first time, demonstrating that the application of S&E knowledge and technical expertise is widespread across the U.S. economy.

In our knowledge-and technology-intensive economy, STEM skills are also required for many in-demand, well-paying careers that are available to workers with less than a bachelor's degree. These jobs, which combine conventional literacy with technical expertise, are concentrated in information technology (IT), health care, and skilled trades. Career and technical education in high schools, community colleges, and certification programs provide vital pathways into this "technical STEM workforce." When these workers are included, there may be as many as 26 million jobs in the U.S. that require significant STEM knowledge and skill in at least one field. This represents nearly 20 percent of all U.S. jobs. Demand for these jobs is distributed nationwide, providing a gateway to opportunity for a segment of the U.S. workforce that has been hard hit by transformations in the domestic and global economy. As Anthony Carnevale, director of the Georgetown Center on Education and Workforce, noted, "There's a new middle. It's tougher, and its takes more skill."

In addition, the new COMPETES framework should recognize that STEM education and training is no longer just for our Nation's young people. To keep pace with the changing global S&E landscape, the U.S. needs to ensure that incumbent workers (both those currently in STEM and those who would like to enter it) have opportunities to upskill and reskill. Given the rapid pace of scientific and technological change in the twenty-first century, STEM-capable workers will need to periodically update their skills. To prepare students and workers for this environment that will demand lifelong learning and reskilling, we must ensure that our STEM education programs create a foundation on which individuals can continuously scaffold new competencies and knowledge; and that government, educational entities, and industry each do their part to make such reskilling and upskilling accessible and affordable.

At the same time that the COMPETES framework recognizes the importance of STEM skills for an ever wider swath of the U.S. workforce, we must recognize that an innovation economy and continued U.S. global leadership cannot be secured through STEM education alone. Arts and humanities education is an essential complement, teaching students interpretive and philosophical modes of inquiry, honing communication and writing skills, fostering multicultural and global understanding, and encouraging an appreciation of history, aesthetics, and the human experience. As a 2013 American Academy of Arts and Sciences report highlighted, study of the humanities and arts develops both critical perspective and imaginative responses, ways of thinking that contribute to inventiveness.

While adopting a broader vision of STEM education and workforce training, the U.S. must continue to support the core of its advanced R&D workforce, doctoral degree recipients. NSF facilitates the education and training of the next generation of scientists and engineers (graduate students as well as postdoctoral 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 six decades, are seminal to U.S. competitiveness and STEM workforce development. The American system of doctoral education is widely considered to be among the world's best, as evidenced by the large and growing number of international students—many of them among the top students in their countries—who choose to pursue the doctoral degree at U.S. universities. However, the continued preeminence of U.S. doctoral education is not assured. Other nations, recognizing the contributions PhD recipients make to economies and cultures, are investing heavily in doctoral education.

Doctorate recipients are the best avenue for transferring basic research discoveries into the technology and biotechnology economies. They begin careers in large and small organizations, teach in colleges and universities, and start new businesses. Among individuals with S&E doctorates, the proportion working in the business sector (46 percent) is similar to the proportion working in the education sector (45 percent). As these data show, doctoral education develops human resources that are critical to the Nation's progress—scientists, engineers, researchers, and scholars who create and share new knowledge and new ways of thinking that lead, directly and indirectly, to innovative products, services, and works of art. In doing so, PhD recipients contribute to a nation's economic growth, cultural development, and rising standard of living.

The COMPETES framework should recognize the importance of this group to our Nation's competitiveness and work toward ensuring that careers in R&D—including those in universities—are attractive to the next generation of scientists and engineers. From the Federal Government standpoint, one key component of this is steady, predictable funding for scientific research. Unpredictable changes to Federal funding for research and "boom-bust" cycles can significantly disrupt the balance between the number of STEM PhDs and the availability of permanent jobs where PhDs can use their specialized training in the academic sector.

The foundation for building this STEM-capable workforce begins with quality primary and secondary STEM education. Almost all of today's STEM jobs require completion of some additional STEM education/training after high school, whether that be a certificate program, coursework, or a degree. K–12 science and math education is therefore critical to preparing students to pursue post-secondary STEM education/training. At a time when more and more individuals in a variety of jobs, including those that were not historically seen as STEM, require STEM capabilities, we need to ensure that all our K–12 students achieve basic STEM literacy. As a nation, our goal should be STEM literacy for all, rather than just for some.

The COMPETES framework should also support continued efforts to attract and retain women and underrepresented minorities in STEM. Although there are some encouraging trends—such as improved high school completion rates, the increasing number of Hispanics earning S&E bachelor's degrees, and an increase in the proportion of S&E PhDs earned by women, there is still much more to be done in this arena. The long-term strength of our workforce requires that the full range of STEM career pathways be available to all Americans. This is a matter of economic opportunity—as I mentioned, STEM jobs are among the highest paid and most recession-resistant of all jobs in the U.S. economy. It is a matter of the robustness of our science; research demonstrates that diverse perspectives are critical to the enterprise. Indeed, the research enterprise is impoverished when individuals from underrepresented groups leave STEM fields or fail to select them to begin with. It matters even more urgently in light of rapidly shifting national demographics, given that Hispanic, blacks, women, and Alaskan/Native students are not obtaining S&E degrees in numbers commensurate with their representation in the U.S. population.

NSF is poised in the coming years to make substantial progress in addressing this. Earlier this year, NSF rolled out Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (INCLUDES), its most ambitious broadening participation endeavor to date. Building upon its history of funding research into what works in STEM education and facilitating its translation into practice, the multi-year INCLUDES program is designed to help take insights and best practice and bring them to scale. Other initiatives that support the development of a more diverse STEM workforce include the Historically Black Colleges and Universities Undergraduate Program (HBCU–UP), the Tribal Colleges and Universities Program (TCUP), and the Louis Stokes Alliance for Minority Participation. As evidence increasingly shows that research experiences early in college are critical to student retention in STEM, the Research Experiences for Undergraduates (REU) program is also poised to play a vital role to bringing in and retaining women and underrepresented minorities.

Innovation and research commercialization

Our nation's innovation ecosystem is the lifeblood of our economy and quality of life. The NSF plays a crucial role in that ecosystem by supporting fundamental research in *all* fields of science and engineering and creating the workforce of the future. Private industry relies on the new knowledge created by basic research to develop new and innovative products and services.

The research that taxpayers have supported for over 60 years through the NSF has advanced our knowledge, developed and supported hundreds of thousands of scientists and engineers, fueled our economy and transformed our way of life by the technologies and processes derived from basic research.

Several NSF initiatives play a vital role in moving innovations from the lab to the marketplace. NSF's I-Corps program seeks to accelerate commercialization and entrepreneurial education. For example, research funded by NSF's Social and Behavioral Sciences on the content of weather advisories and warnings, the communications channels used, and on how residents comprehend specific advisories and warnings highlighted that use of tailored messages is critical to saving lives. Professors Carol Silva and Hank Jenkins-Smith—both Political Scientists at the University of Oklahoma—have conducted groundbreaking research in these areas. Building off their NSF-funded basic research, Dan O'Hair and his team at the University of Kentucky are, with the help of an NSF I-Corps grants, exploring ways to commercialize their research on tailored storm warning communication. This is both a commercial and humanitarian opportunity, and one that highlights how fundamental research—in this case in the social sciences—can help catalyze new businesses.

NSF's Small Business Innovation Research/Small Business Technology Transfer (SBIR/STTR) program seeks to transform scientific discovery into societal and economic benefit by catalyzing private sector commercialization of technological innovations. The program increases the incentive and opportunity for startups and small businesses to undertake cutting-edge, high-quality scientific research and development. NSF is working to better connect the I-Corps program with existing SBIR/STTR programs.

The agency's EPSCoR program ensures that all geographic regions in the U.S. contribute to S&E research and education by providing research capacity-building funding. EPSCoR also plays an important role in economic development across this country. I would never have been able to start my company, Weather Decision Technologies, were it not for EPSCoR, which helped support one of NSF's first Science and Technology Centers. This center, which I directed at the University of Oklahoma, pioneered a new science of computer-based prediction of thunderstorms and led to the founding of the company, which today employs over 80 people.

Finally, I wish to highlight the importance of academic-corporate-government partnerships in the innovation ecosystem. Research universities are important engines of local, regional and national economic development. However, in spite of the dramatic increase in private investment in R&D over the past 20 years, very little of this increase has come to universities.

One of the primary barriers to greater university-industry partnership is that Federal tax laws place significant restrictions on universities' ability to negotiate intellectual property terms at the front end of a contract. Lack of certainty about cost makes it difficult for private companies to create business plans, based upon intellectual property licenses from universities that are acceptable to corporate leadership and shareholders.

In its recent report *Restoring the Foundation,* the American Academy of Arts and Sciences recommended modifications to Federal tax law to remove impediments to corporate-academic partnerships. The America COMPETES re-authorization would do well to consider this issue and unlock the potential of corporate-academic collaboration.

Conclusion

Just over 65 years ago, James Conant, the first Chair of the National Science Board, wrote, "No one should expect to be able to assess in a short interval of time the value of the money spent on scientific investigations. Even in the field of applied science, research is in the nature of a long-term investment." Having just concluded twelve years on the Board, I am more convinced than ever that this long-term national investment in fundamental science, research infrastructure, and STEM education is essential to our future health, security, and prosperity. In a world where science today 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 continues to open new frontiers by balancing its longstanding "grass roots" vision of science with an agency-wide commitment to fund research addressing our Nation's priorities.

Our challenge now is to find ways to sustain the U.S. science and engineering enterprise at a time when budgetary pressures are limiting our resources. But we can't let that stop us from continuing to dream big—America's greatest asset is our creativity and freedom to explore. We need to leverage NSF resources with interagency collaborations that extend the reach and yield of NSF investments and encourage academic-industry partnerships. We need to maximize the dollars that go to research by reducing administrative burdens. We need to build on successful NSF programs that spur the transfer of knowledge to commercialization. And we need to remove obstacles and create opportunities to develop the STEM-capable U.S. workforce required for an increasingly multi-polar and knowledge-intensive world.

My colleagues in the scientific community and I commend this bipartisan effort, and urge your continued support of NSF, the research enterprise, and the Nation's bold—but essential—quest to advance the "endless frontier."

The CHAIRMAN. Thank you, Dr. Droegemeier.

Dr. Wing.

STATEMENT OF JEANNETTE WING, CORPORATE VICE PRESIDENT, MICROSOFT RESEARCH, MICROSOFT CORPORATION; MEMBER OF THE AMERICAN ACADEMY OF ARTS AND SCIENCES COMMITTEE ON NEW MODES FOR U.S. SCIENCE AND TECHNOLOGY POLICY

Dr. WING. Chairman Thune, Ranking Member Peters, and members of the Committee, thank you for inviting me to speak about the Federal Government's role in supporting research.

As Corporate Vice President of Microsoft Research, I lead Microsoft's basic research laboratories worldwide. My purpose today, however, is to describe the conclusions and recommendations from a recent report from the American Academy of Arts and Sciences titled "Restoring the Foundation: The Vital Role of Research in Preserving the American Dream."

I was honored to serve on the Committee that produced the report. While my testimony generally adheres to our conclusions, my remarks represent my own views, and not necessarily those of our study group, the American Academy, or Microsoft.

America is losing ground to other nations in R&D, particularly in the fundamental curiosity-driven research that is so critical for elevating our standard of living and driving economic growth. In my field of information technology, for example, basic research from the 1970s on parallel and distributed systems ultimately led to cloud computing, which is completely transforming how businesses in all sectors operate. And cloud computing is only one of many billion-dollar markets that have grown from the interplay between federally-funded research at universities and private-sector innovation.

It is, therefore, alarming that neither the Federal investment in basic research nor the policies that govern such research has kept pace with the remarkable changes occurring in the global competitive environment. To correct this problem, "Restoring the Foundation" offers recommendations to achieve three objectives:

First, securing America's leadership in science and engineering by providing sustainable growth in the Federal investment in basic research. Over the past two decades, America has dropped to tenth place globally in investments in R&D, and seventh place in basic research. Strikingly, China is projected to overtake us in R&D investment in just 6 years, both as a percentage of GDP and in absolute dollars.

Mindful of current fiscal constraints, our committee recommends that the Federal Government commit to an annual real growth of at least 4 percent for the Federal investment in basic research. This recommendation is based on the observation that, from 1975 to 1992, Federal investment in basic research grew at an average annual inflation-adjusted rate of 4.4 percent, despite serious political and economic challenges. Members of Congress on both sides of the aisle recognized that investments in basic research were just that, investments in the long-term health, security, and prosperity of Americans from all walks of life.

The second objective is to maximize the benefit that our taxpayers receive from Federal investments in research. Among its recommendations, "Restoring the Foundation" asks Congress to reaffirm merit-based peer review as the basis for awarding research grants in America, leaving primary responsibility for evaluating research proposals in the hands of scientific experts and the relevant agencies. I thank this committee for upholding this principle, including in the case of the social and behavioral sciences, which are critical for understanding the challenges we face as a country.

The third objective identified by the American Academy report is to regain America's standing as an innovation leader by establishing a more robust national government/university/industry research partnership. For example, academic institutions should be encouraged to experiment with new technology transfer policies that would promote innovation and job creation while reducing the time and cost of licensing.

The business community strongly supports all of the recommendations that I have mentioned. Last summer, ten American business leaders, including the CEO of my company, Microsoft, issued a call to action entitled "Innovation: An American Imperative." It urges Congress to take seven specific actions, including those that I have described, to ensure that the U.S. remains the global leader in innovation.

Congress has already implemented one of those actions, making permanent the R&D tax credit. Members of Congress have an opportunity to consider additional actions that will help restore research as a national priority.

Thank you again for inviting me to participate in today's hearing. I look forward to your questions.

[The prepared statement of Dr. Wing follows:]

PREPARED STATEMENT OF JEANNETTE WING, CORPORATE VICE PRESIDENT, MICROSOFT RESEARCH, MICROSOFT CORPORATION; MEMBER OF THE AMERICAN ACADEMY OF ARTS AND SCIENCES COMMITTEE ON NEW MODES FOR U.S. SCIENCE AND TECHNOLOGY POLICY

Chairman Thune, Ranking Member Nelson, and Members of the Committee: Thank you for inviting me to speak here today about the Federal Government's role in supporting research. I am Corporate Vice President of Microsoft Research, head of Microsoft's basic research laboratories worldwide. From 2007 to 2010, I was Assistant Director of the Computer and Information Science and Engineering Directorate at the National Science Foundation. I served twice as Head of the Department of Computer Science at Carnegie Mellon University, and was the President's Professor of Computer Science. I am currently an adjunct faculty member at Carnegie Mellon University. Prior to CMU, I served on the faculty at the University of Southern California for two years. As a student, I worked at Bell Laboratories and at Xerox Palo Alto Research Centers (PARC). I am currently Chair of the DARPA Information Science and Technology study group and Chair of the Informa-

tion, Computing, and Communication Section of the American Association for the Advancement of Science. My comments today will reflect the diversity of my experiences in many sectors of the research system. Indeed, the recommendations from the American Academy of Arts and Sciences report that I will be discussing have found broad support in all of these sectors, from academia to government to industry.

I appear here today to discuss the American Academy of Arts and Sciences report, *Restoring the Foundation: The Vital Role of Research in Preserving the American Dream.* The American Academy of Arts and Sciences was founded in 1780 by John Adams and other scholar-patriots to foster dialogue among leaders of science, the arts, business and public affairs. Today, the American Academy remains an independent policy research institute, applying cutting-edge scholarship to find solutions to critical societal problems.

I had the privilege to serve on the American Academy's committee that produced the *Restoring the Foundation* report. This committee was co-chaired by former Lockheed Martin Chairman and CEO, Norman Augustine, and former National Science Foundation Director, Neal Lane, now of Rice University. Our study group was tasked with evaluating how to ensure the long-term sustainability of the U.S. science and engineering research enterprise. Neal Lane had the opportunity to testify before this Senate committee in July 2014 in advance of the report's publication. He spoke broadly about the state of the U.S. research enterprise and alluded to many of the recommendations that were published by the American Academy two months later. These policy recommendations have found support on both sides of the aisle. I would especially like to thank Senators Thune, Nelson, Gardner, and Peters for their leadership in convening numerous roundtables with the research community to explore productive steps we can take together. Our report committee has been encouraged by the tone of these conversations, and I am grateful for the opportunity to tell you more about the conclusions and recommendations from *Restoring the Foundation.* While the testimony I will present to you today generally adheres to the Committee's conclusions, the remarks represent my own views and not necessarily those of the study group, the American Academy, or Microsoft.

The Value of Curiosity-Driven Research

America is increasingly losing ground to other nations in research and development (R&D), particularly in the basic research that plays such a central role in American innovation. Basic research refers to scientific studies that aim to contribute to the larger body of knowledge and advance our understanding on the fundamental aspects of natural phenomena without the goal of a specific application or product. During and after World War II, the U.S. made a new national commitment towards sustaining curiosity-driven research at universities across the country. This basic research has led to many notable breakthroughs over the past sixty years, and these investments continue to drive the innovation of new products today. One of my colleagues on the Restoring the Foundation committee, Mark Fishman, the former President of Novartis Institutes for BioMedical Research, often observes that, on average, it takes forty years for a discovery in biology to lead to a new drug or product. For example, the development of recombinant DNA techniques in the 1970s spurred the biotechnology revolution, creating advancements in numerous industries including medicine, agriculture, and manufacturing. Recombinant DNA made possible the development of synthetic human insulin to treat diabetes, the hepatitis B vaccine, and crops engineered to be resistant to pests and chemicals. In short, it led to many billion-dollar industries and opened up new research frontiers.

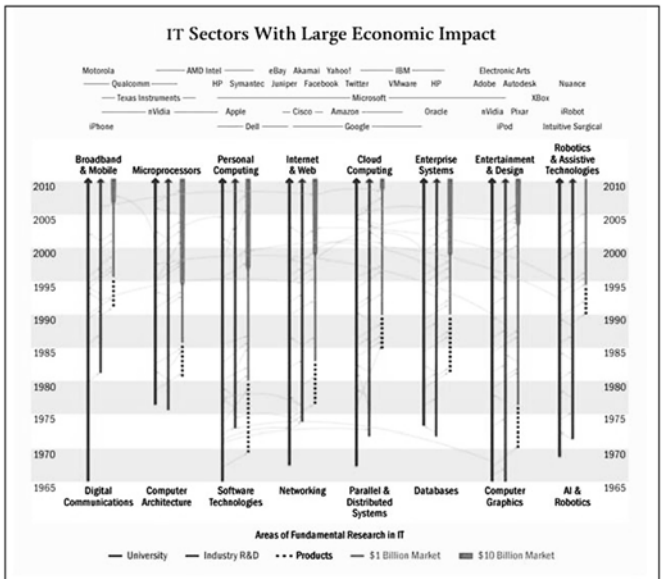
The far-reaching benefits of federally-supported research are not limited to the biomedical sciences. Last week, the Breakthrough Prize in Physics was awarded to the three founders of the Laser Interferometer Gravitational-Wave Observatory (LIGO) and the hundreds of other contributors to the project who, after many years of hard work, made the first direct detection of gravitational waves predicted by Einstein a century ago. The National Science Foundation has been funding work that led to this discovery since the 1970s. Forty years later, the development of a tool to detect gravitational waves makes it possible to learn more about our universe and ask deeper questions about its origins. The technologies that made LIGO possible also have many additional uses and have facilitated the development and commercialization of new technologies such as creating more uniform optical coatings and improving materials used to build the structural components of aircraft.[1] In

[1] Advanced LIGO: Extending the Physics Reach of LIGO. *https://www.advancedligo.mit.edu/tech__overview.html*

fact, most new technologies are traceable to research projects where the scientists could not foresee the future applications and impact of their work.

Curiosity-driven research not only leads to advances in medicine and technology, but is also responsible for fueling economic growth. Multiple economic analyses—including Nobel Prize winning research—support that over half of all sustained economic growth since World War II results directly from scientific and technological advances. Hundreds of companies have their origins in federally-funded research conducted in a university. In my field of Information Technology, basic research on parallel and distributed systems starting in the 1970s ultimately led to Cloud Computing, which has completely transformed how businesses in all sectors operate by facilitating the storage and on-demand retrieval and analysis of massive amounts of data.

Also in the 1970s, basic research in information retrieval and networking led to the Internet search engines we take for granted today, completely transforming how people find information on the web and interact with each other professionally and socially. This pattern has been broadly true in Information Technology, as you can see in the graph below, which is often described as the "tire tracks" diagram. This graph, which is reproduced from the 2012 National Academies report *Continuing Innovation in Information Technology*, depicts the network of university and industry contributions that over the years has led to the creation of information technology firms and products with $1 billion and even $10 billion markets.[2] These innovations not only led to new industries, but also profoundly changed society in ways that we never could have predicted.



Innovation is Not Linear, but a Highly Interconnected Web

Examples of the contributions of federally supported fundamental research to the creation of information technology (IT) firms and products with large economic impact. Red tracks: university-based research. Blue tracks: industry R&D. Dashed black lines: periods following the introduction of significant commercial products resulting from fundamental research. Green lines: billion-dollar-plus industries (by annual revenue) stemming from fundamental research. Thick green lines: achievement of multibillion-dollar markets by some industries. Arrows between tracks: multidirectional flows of ideas, technologies, and people. Top rows: present-day it market segments and representative U.S. firms and products whose creation was stimulated by the research represented by the red and blue vertical tracks. Bottom row: areas of fundamental research in it.

Source: National Research Council, *Continuing Innovation in Information Technology* (Washington, D.C.: The National Academies Press, 2012), 3.

From *Restoring the Foundation: The Vital Role of Research in Preserving the American Dream* (American Academy of Arts & Sciences, 2014)

[2] Source: National Research Council, *Continuing Innovation in Information Technology* (Washington, D.C.: The National Academies Press, 2012), 3.

I hope it is evident that while basic research may have no *intended* end goal, it is in fact the foundation of American prosperity and progress.

Improving U.S. Innovation Competitiveness

While most of America's innovations, as well as its quality jobs, are created in private industry, companies depend on a continuous stream of new scientific discoveries and early-stage technologies that flow from the Federal Government's investments in research, particularly basic research, carried out at research universities and national laboratories. So it is alarming that the Federal Government's investment in basic research has been slowly eroding over the past two decades—and it should be alarming not just for the scientific community, but for the entire American people. This concern motivated the American Academy to assemble a committee of 25 leaders spanning the research enterprise—including from government, universities, businesses and industry—to consider how to address this issue. The committee published *Restoring the Foundation* in September 2014. The report summarizes the Committee's recommendations for policy changes in academia, industry, and government. *Restoring the Foundation* was immediately endorsed by leaders throughout the private and public sectors, including the Presidents of Merck, the Business Roundtable, the Association of American Universities, and the Association of Land-grant and Public Universities, among many others.

Nearly two years ago, report co-chair Neal Lane had the chance to testify before this committee in advance of the report's publication. I am pleased to be here today to discuss the Committee's published recommendations and the impressive amount of backing that the work has received across all sectors of the economy. We have had many opportunities to discuss the report with individual Members and have greatly appreciated the substantial interest and support our recommendations have received from both sides of the aisle.

Restoring the Foundation focuses particularly on basic research, the imperiled foundation upon which the Nation's leadership in innovation and prosperity rests. The report offers recommendations to meet three critical objectives:

- ***Ensure*** *that the American people receive the maximum benefit from Federal investments in research;*
- ***Regain*** *America's standing as an innovation leader by establishing a more robust national government-university-industry research partnership; and*
- ***Secure*** *America's leadership in science and engineering research—especially basic research—by providing sustainable Federal investments.*

I will use the rest of my testimony to describe in detail a few specific recommendations that may be especially helpful for this Senate committee to consider as it explores ways to promote the health and productivity of American research. There are several recommendations from *Restoring the Foundation* that I will not cover here, such as on capital budgeting for research instrumentation; university cost-containment efforts and resource sharing with outside parties; and expanding the science, engineering and technology assessment capabilities of the Government Accountability Office. More information on these recommendations can be found in our report, and I would also be happy to discuss any questions you may have at a later date.

Ensuring that the American People Receive the Maximum Benefit from Federal Investments in Research

A skilled workforce provides a tremendous return on Federal investment; therefore, it is imperative that scientists and engineers dedicate the majority of their time to the research activity that drives the U.S. innovation ecosystem. However, added rules and regulations have diverted researchers' time and focus from their intended jobs and created unnecessary administrative overhead. The National Science Board's 2014 report, *Reducing Investigators' Administrative Workload for Federally Funded Research,* cited a 2005 finding from the Federal Demonstration Partnership that federally-supported researchers spend, on average, 42 percent of their time on administrative tasks. Seven years later, that average remained at 42 percent despite collective efforts to alleviate regulatory burdens on researchers.

In light of recent recommendations issued by the National Academies of Sciences, Engineering, and Medicine in their 2015 report *Optimizing the Nation's Investment in Academic Research: A New Regulatory Framework for the 21st Century,* the time is right for Congress to consider implementing specific changes to reduce the amount of paperwork that is required of researchers. Here I would like to acknowledge the leadership that Senators Lamar Alexander and Patty Murray have shown in encouraging the Senate Committee on Health, Education, Labor, and Pensions to advance a number of the recommendations contained in the National Academies

report. I urge this committee to do the same for the agencies under your jurisdiction.

Merit-based peer review has long been upheld by researchers as the gold standard for ensuring scientific excellence, integrity, competitiveness as well as the most effective use of taxpayer dollars. *Restoring the Foundation* asks Congress to reaffirm that this gold standard should remain the practice for awarding research grants in America, leaving primary responsibility for evaluating the scientific merit of the research proposals in the hands of the relevant agencies and scientific experts. I should note that the American Academy committee has been gratified that so many in Congress on both sides of the aisle agree with this principle, and that this Senate committee has upheld it for the agencies under its jurisdiction—including in the case of the social and behavioral sciences and the research in these fields that is so important for understanding the challenges we face as a country. For example, in my field of Information Technology, social science research continues to suggest new approaches for thwarting cybercrime and protecting American's privacy and security in an increasingly connected world.

Regain America's Standing as an Innovation Leader by Establishing a More Robust National Government-University-Industry Research Partnership

The report committee makes several recommendations to strengthen ties between government, universities, and industry. American companies today–most of them lacking large central research operations and some of them, including those in the pharmaceutical sector, having considerably reduced their R&D activity–have formed collaborations with universities and national laboratories that over time could develop as a national partnership. But there are still barriers that require our attention, including policies on intellectual property, management of potential conflicts of interest, and publication restrictions.

I would like to focus on one of the report committee's suggestions regarding technology transfer. Specifically, the Committee suggests that Congress assist academic institutions in adopting new technology transfer policies that would promote innovation and job creation while reducing the time and cost of licensing. The Bayh-Dole Act, which allows universities, small businesses, and nonprofit organizations to pursue ownership of an invention arising from federally-funded research, has been highly effective in advancing to market the intellectual property (IP) generated from federally-funded research. Over several decades, however, it has become clear that modification of certain policies and regulations could further propel the flow of IP to market by promoting start-ups and government-university-industry partnerships. The majority of universities have found that the cost of maintaining a technology transfer office, filing for patents, and negotiating IP licensing exceeds the income generated from licensing. Licensing negotiations with companies can also pose a high barrier to collaboration, often delaying or preventing the transfer of technologies to a company and, potentially, to market.

More universities should experiment with new policies to enhance the transfer of IP to the market. My previous employer, Carnegie Mellon University (CMU) has fundamentally changed the way it approaches technology commercialization. The University deemphasized revenue generation and created a process dubbed by former CMU Provost Mark Kamlet as the "5 percent and go in peace" policy, which eliminated or greatly reduced the need for faculty to negotiate with the institution.[3] The outcomes of these policies should be evaluated to derive best practices, while staying mindful of potential conflicts of interest, restrictions on public access to research results, and the potential for resulting constraints on future research conducted in university and government laboratories.

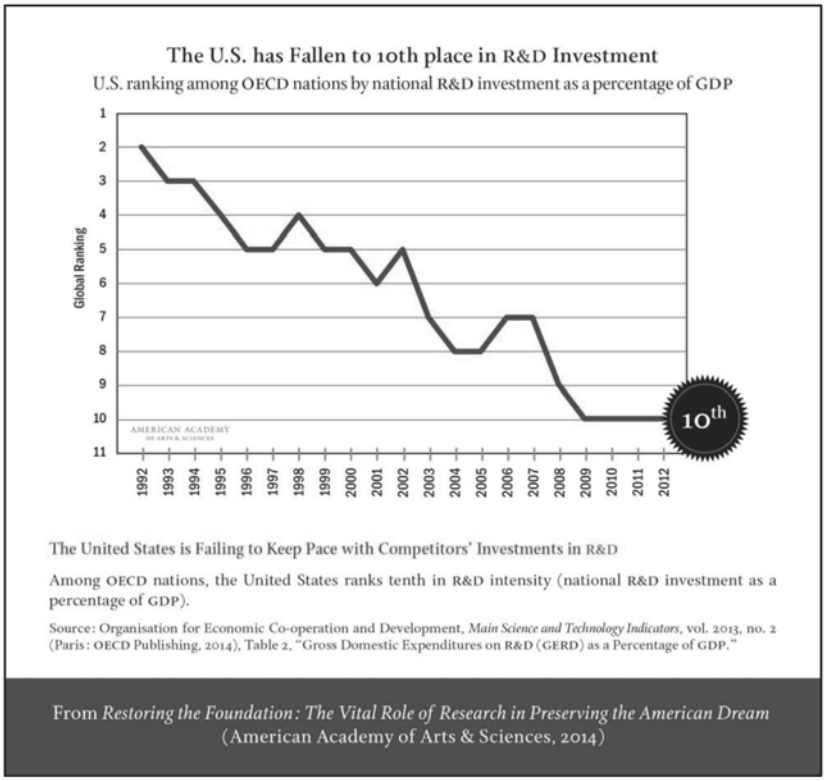
Secure America's Leadership in Science and Engineering Research—Especially Basic Research—by Providing Sustainable Federal Investments

I would be remiss if I did not mention our committee's recommendations pertaining to the Federal investment in science. The committee recognizes that we are in a time of fiscal constraint and that Congress has many priorities. Nevertheless, after much analysis and debate, we concluded that the U.S. will not remain competitive with other countries unless we find a way to increase funding in basic research.

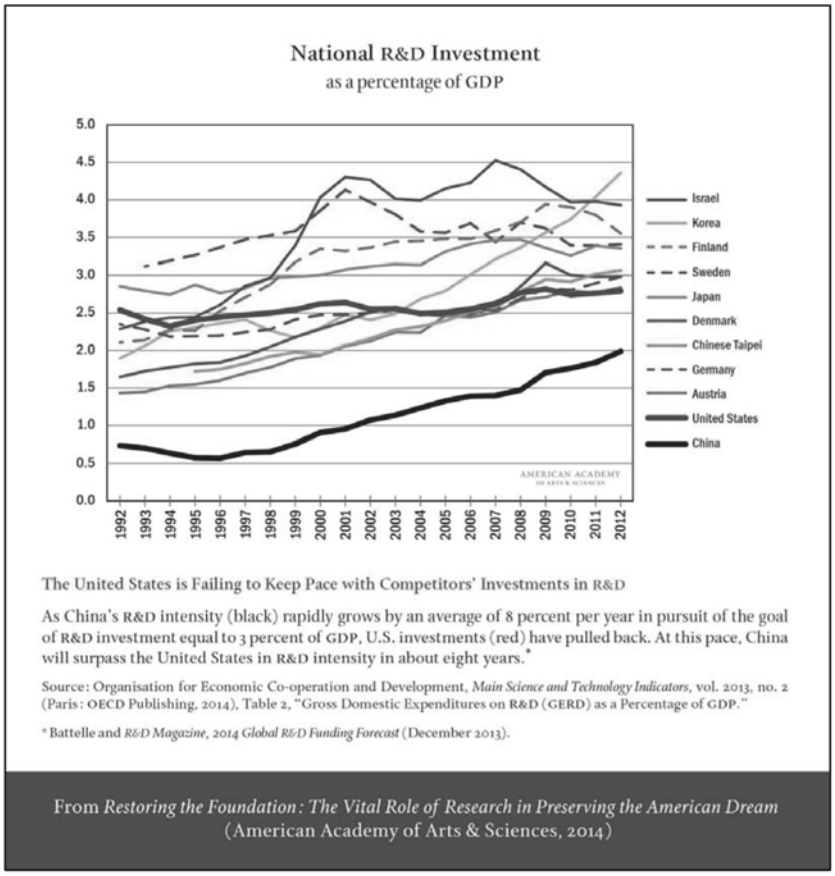
While the U.S. was the global leader in science innovation for years, it has recently forfeited this position to other countries like Korea and Japan, as the U.S. investment in R&D continues to fall short of other nations. The total U.S. investment (public and private) in R&D measured as a percentage of GDP—an accepted metric for the country's commitment to the future of its citizens—continues to fall

[3] See Focus Section C, pg. 71, from the 2014 American Academy of Arts and Sciences report *Restoring the Foundation: The Vital Role of Research in Preserving the American Dream.*

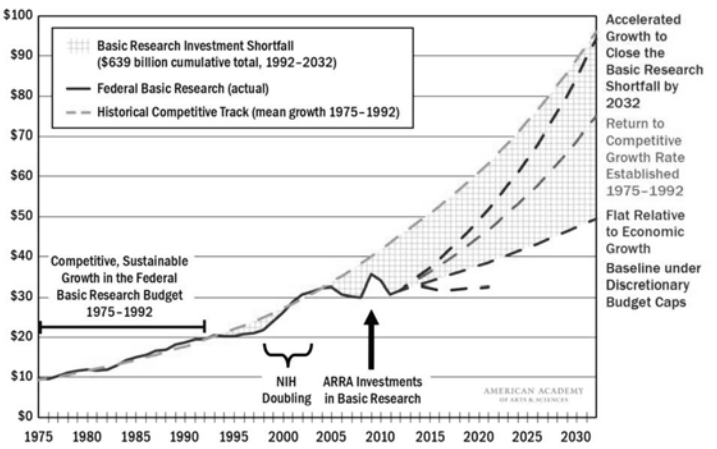
short of the national goal of at least 3 percent adopted by several U.S. presidents, even as America's economic competitors move aggressively to increase their own investments in innovation. As the following graph shows, the U.S. has dropped to 10th place globally in investments in R&D when measured as a function of economic output. And even in basic research, long a particular area of strength for the United States, we are now in 7th place by this measure.



And as the next graph shows, other nations are well on their way to achieving the goal of investing at least 3 percent GDP in R&D, and many have surpassed it. China will pass us in absolute R&D spending within eight years.



With these concerns in mind, the Committee recommends that the country commit to an annual real growth rate of at least 4 percent for basic research. We recognize that the country is still recovering from the recent recession, yet as *Restoring the Foundation* notes, from 1975 to 1992 the Federal investment in basic research grew at an average annual inflation-adjusted rate of 4.4 percent despite serious political and economic challenges, including the 1973 oil embargo, the Great Inflation of 1979–1982, and the final tumultuous years of the Cold War. During this period, Republicans and Democrats, in spite of a number of policy differences, were in agreement that Federal funding of basic research was a national priority. However, in the subsequent two decades, from 1992–2012, even taking into account the doubling of the NIH budget, the average growth rate was roughly 0 percent. It is notable that 1992, the last year the U.S. had a 4 percent growth rate in basic research, is also the year that the U.S. began falling behind other nations in our R&D investment. The following graph illustrates these data:



Getting U.S. Basic Research Back on Track

Should federal obligations for basic research (blue) flatline relative to economic growth, the United States will by 2032 have accumulated a $639 billion shortfall (cross-hatch) in federal support of basic research relative to the 4.4 percent average annual real growth trend (orange) established during the period of 1975 to 1992. This committee recommends that the nation return to this historical competitive growth rate (green), with the ultimate goal of fully closing the basic research shortfall (purple) as the economy improves.

Note: Orange trend line is a best fit (least squares regression) of federal obligations for basic research (constant 2014 dollars) between 1975 and 1992.

Source: Federal obligations for basic research from 1975 to 2012 are from National Science Board, *Science and Engineering Indicators 2014* (Arlington, Va.: National Science Foundation, 2014), Appendix Table 4-34, "Federal Obligations for R&D and R&D Plant, by Character of Work: FYs 1953–2012." Basic research funding baseline projections are based on the nondefense discretionary funding levels from the Office of Management and Budget, *Fiscal Year 2015 Budget of the U.S. Government* (Washington, D.C.: Office of Management and Budget, 2014), Table S-10, "Funding Levels for Appropriated ('Discretionary') Programs by Category," whose baseline levels assume Joint Committee enforcement cap reductions are in effect through 2021. GDP projections assume an average real annual growth rate of 2.2 percent until 2020 and 2.3 percent from 2020 to 2030, according to Jean Chateau, Cuauhtemoc Rebolledo, and Rob Dellink, "An Economic Projection to 2050: The OECD 'ENV-Linkages' Model Baseline," *OECD Environment Working Papers*, No. 41 (Paris: OECD Publishing, 2011), Table 4, doi:10.1787/5kgondkjvfhf-en.

From *Restoring the Foundation: The Vital Role of Research in Preserving the American Dream*
(American Academy of Arts & Sciences, 2014)

A 4 percent growth rate is a modest number when applied to basic research. Since the Federal investment in such research is roughly $30 billion per year, 4 percent growth corresponds to a long-range target of increasing the Federal basic research investment from 0.2 percent to 0.3 percent of GDP over a period of 10 to 15 years. We have been very encouraged by the bipartisan interest in supporting science and engineering and the general agreement with the imperative of establishing a sustainable growth trajectory for basic research. Importantly, our committee recommended that any additional investment in basic research should not come at the expense of Federal support for applied research and development or funding for specific scientific fields. These investments are also critical for America's global competitiveness and such a trade-off would thus be counter-productive.

Both the Federal Government and industry contribute to R&D. But although U.S. industry funds and performs roughly 2/3 of the Nation's R&D, these activities focus primarily on development rather than basic research. While my company continues to benefit from a robust research program, most companies lack large central research operations and cannot afford to fund basic research due to the risk of being penalized by corporate shareholders who do not prioritize such long-term invest-

ments. Additionally, while most of America's innovations, as well as its quality jobs, are created in private industry, companies depend on a continuous stream of new scientific discoveries and early-stage technologies that flow from the Federal Government's investments in research, particularly basic research, carried out at research universities and national laboratories. This is clearly depicted in the tire tracks diagram discussed earlier. Federal investments in research also support the training of future scientists and engineers through graduate programs and postdoctoral fellowships, functioning to replenish the scientific workforce and fuel the talent pipeline.

For these reasons the Federal Government will remain the primary funder of the fundamental, curiosity-driven research on which all innovation depends. While the scientific community recognizes that this is a period of financial constraint for the Federal Government, it is imperative that the government recognizes that investments in basic science research are just that—investments. To address U.S. global innovation competitiveness, we must reexamine our basic science research enterprise and determine how to ensure that the American people receive the maximum benefit from Federal investments in research and identify how the Federal Government can support a sustainable trajectory for future research.

Steady, sustainable increases in Federal investment would go a long way to restoring American leadership. The current strategy for Federal research funding relies on annual budget cycles, hindering the long-term planning required to give researchers predictability for successfully executing groundbreaking research, and resulting in costly inefficiencies in grant programs. The committee recommends that the President and Congress adopt a more strategic, multiyear approach to funding that better reflects the long-term nature of basic research, possibly through a rolling 5–10 year plan. Multiyear appropriations should be prioritized for agencies that primarily support research and graduate STEM education to strengthen the future research workforce. We also recommend that the White House Office of Management and Budget establish a strategic capital budget process for Federal R&D, particularly the construction of research instrumentation and facilities that take many years to plan and build.

Overwhelming Support

Since the release of *Restoring the Foundation,* members of the report committee and American Academy staff have met with many Members of Congress and their staff from both sides of the aisle, including meetings with Senators from this committee, to discuss the report recommendations. The overwhelmingly supportive response is a true testimony to the bipartisan spirit of these recommendations. We are grateful for the thoughtful discussions with you and your staff about how to turn them into policy.

These recommendations have also found strong support in the business community. Last summer, ten CEOs and corporate chairmen—including the CEOs of Lockheed Martin, Northrop Grumman, Boeing, John Deere, Merck, Novartis, the National Association of Manufacturers, and my company, Microsoft—issued a call to action entitled "Innovation: An American Imperative." The statement, which is attached to this testimony, urges Congress to take decisive action to ensure the U.S. remains the leader in global innovation. The Innovation Imperative identifies seven specific policy recommendations, many of which echo those in the *Restoring the Foundation* report, for how to achieve this goal:

1. Renew the Federal commitment to scientific discovery
2. Make permanent a strengthened Federal R&D tax credit
3. Improve student achievement in science, technology, engineering, mathematics (STEM)
4. Reform U.S. visa policy
5. Take steps to streamline or eliminate costly and inefficient regulations
6. Reaffirm merit-based peer review
7. Stimulate further improvements in advanced manufacturing

One of the proposed action items, making permanent the R&D tax credit for businesses, has already been implemented by Congress, which will encourage American corporations to strengthen their investments in long-range research.

I would like to draw attention to the Innovation Imperative recommendation on STEM education, since computer science education, namely computational thinking, has long been an interest of mine. Today computing touches every sector, every discipline, and every profession. Industry in all sectors recognizes the importance of computer science for their future and the demand for a workforce skilled in computing is increasing, far outweighing the supply.

The Innovation Imperative has now been endorsed by more than 325 leading companies and organizations representing science and engineering research, American industry, and higher education, including at least one from each of the 50 states. All have come together to say that a sustained commitment to basic research should be a high priority for Congress. I am extremely proud that my CEO, Satya Nadella, was among the corporate leaders who signed the Innovation Imperative. To me, it means Microsoft understands and believes in the value of basic research—for the company and for the country.

I am also enormously appreciative that Senators Lamar Alexander and Chris Coons, in addition to Representatives Derek Kilmer and Randy Hultgren, recently issued a Dear Colleague Letter in support of the Innovation Imperative statement. This hearing provides another opportunity for Members of Congress to come together to find practical solutions to restoring research to its rightful place as a national priority and structuring the U.S. research enterprise to efficiently carry out that mission. I look forward to working with members of the Senate Committee on Commerce, Science and Transportation to explore how all stakeholders in the research system can get together to advance these goals.

Conclusion

Congress is poised to get the U.S research enterprise back on track, and your interest and hard work is greatly appreciated by the scientific community. I would like to close by emphasizing three policy recommendations that the American Academy committee that produced the *Restoring the Foundation* report believes are particularly crucial for the long-term prosperity of this nation, and have strong backing among businesses and universities alike: (1) relieving regulatory burdens that limit the productivity of America's researchers; (2) encouraging more robust research partnerships among Federal and state governments, public and private universities, and industry; and (3) establishing sustainable annual real growth of at least 4 percent in the Federal investment in basic research and a long-term investment goal of 0.3 percent of GDP. Failing to put these recommendations into action would put the U.S. at risk of conceding our leadership in basic research to our economic competitors around the world. Doing so would forfeit our leadership in the technologies and markets of tomorrow and the opportunity to create jobs at all stages of the innovation pipeline.

Thank you again for the invitation to speak before this committee today. Please do not hesitate to reach out to me, the American Academy staff, and our report committee if you would like to discuss our recommendations in more detail. I look forward to taking your questions.

INNOVATION: AN AMERICAN IMPERATIVE

A call to action by American industry, higher education, science, and engineering leaders urging Congress to enact policies and make investments that ensure the United States remains the global innovation leader.

Our nation knows what it takes to innovate: a sustained commitment to scientific research, a world-class workforce, and an economic climate that rewards entrepreneurship and innovation. As the most dynamic and prosperous nation in the world, the United States has long benefitted from policies and investments that have promoted innovation and in turn driven productivity and economic growth, bolstered American trade, ensured our health and national security, and safeguarded the American dream. Our leadership is now at risk because of years of under-prioritizing federal scientific research investments and policies that promote innovation.

Now is not the time to rest on past success. As noted by the American Academy of Arts and Sciences in its 2014 Report *Restoring the Foundation: The Vital Role of Research in Preserving the American Dream*, "There is a deficit between what America is investing and what it should be investing to remain competitive, not only in research but in innovation and job creation." Competitor nations are challenging our leadership by copying our playbook for success. At the same time our nation's support for scientific research and innovation is stagnating. If these trends continue, other countries will soon surpass the United States as the global innovation leader.

We must heed the warnings in the *Restoring the Foundation* report and other salient reports of the past decade and act decisively. In particular, Congress must:

Renew the federal commitment to scientific discovery
by ending sequestration's deep cuts to discretionary spending caps and providing steady and sustained real growth in funding of at least four percent for basic scientific research at: the National Science Foundation, the National Institutes of Health, the Department of Energy's Office of Science, the Department of Defense, NASA, the National Institute of Standards and Technology, USDA, and NOAA;

Make permanent a strengthened federal R&D tax credit
as a part of comprehensive tax reform to encourage more private-sector innovation investment here in America instead of in competitor countries;

Improve student achievement in science, technology, engineering, mathematics (STEM)
through increased funding of proven programs and incentives for science and math teacher recruitment and professional development;

Reform U.S. visa policy
to welcome and keep highly educated international professionals, particularly those holding STEM degrees from U.S. universities;

Take steps to streamline or eliminate costly and inefficient regulations
and practices governing federally funded research to help unburden researchers to focus more time on conducting research and training the next generation of scientists, engineers, health care professionals, and business leaders;

Reaffirm merit-based peer review
as the primary mechanism major federal agencies should employ in making competitive scientific research grants to ensure the most effective use of taxpayer dollars; and

Stimulate further improvements in advanced manufacturing
through support for programs aimed at accelerating manufacturing innovation and new federal-industry-academic partnerships.

We, the signatories, urge support for these actions to keep the United States the global innovation leader. We stand ready to do our part.

Samuel R. Allen
Chairman & CEO
John Deere

Norman R. Augustine
Co-Chair
Restoring the Foundation

Wes Bush
Chairman, President & CEO
Northrop Grumman

Kenneth C. Frazier
Chairman & CEO
Merck & Co., Inc

Marillyn A. Hewson
Chairman, President, & CEO
Lockheed Martin Corporation

Charles O. Holliday
Chairman
Royal Dutch Shell plc

Joseph Jimenez
CEO
Novartis

W. James McNerney, Jr.
Chairman of the Board & CEO
The Boeing Company

Satya Nadella
CEO
Microsoft

Jay Timmons
President & CEO
National Association of Manufacturers

This document – along with news, op-eds and resources relating to the Innovation Imperative – can be found at innovationimperative.org

Academy of Radiology Research
Acoustical Society of America
Ad Hoc Group for Medical Research
Adv. Technical Intelligence Assn.
Aerospace Industries Association
Agricultural & Applied Economics Association
Aizoon Technology Consulting
AMD
American Academy of Arts & Sciences
American Anthropological Association
American Association for Dental Research
American Association for the Advancement of Science
American Association for the Study of Liver Diseases
American Association of Colleges of Pharmacy
American Association of Mycobacterial Diseases
American Association of Petroleum Geologists
American Association of Physical Anthropologists
American Association of Physicists in Medicine
American Association of Physics Teachers
American Association of State Colleges and Universities
American Astronomical Society
American Chemical Society
American Council on Education
American Dairy Science Association
American Dental Education Association
American Educational Research Association
American Geophysical Union
American Geosciences Institute
American Institute for Medical & Bio. Engineering
American Institute of Aeronautics and Astronautics
American Institute of Chemists
American Institute of Physics
American Mathematical Society
American Meteorological Society
American Physical Society
American Physiological Society
American Phytopathological Society
American Political Science Association
American Psychological Association
American Society for Biochemistry and Molecular Biology
American Society for Engineering Education
American Society for Microbiology
American Society for Nutrition
American Society of Agronomy
American Society of Animal Science
American Society of Plant Biologists
American Sociological Association
American Veterinary Medical Association
Anchorage Economic Development Corporation
Applied Materials, Inc
Archaeological Institute of America
Arizona Nevada Academy of Science (ANAS)
Arizona State University
Arkansas Research Alliance
Arkansas State University
ASME
Association for Information Science and Technology
Association for Psychological Science
Association for Women in Mathematics
Association for Women in Science
Association of American Geographers
Association of American Medical Colleges
Association of American Universities
Association of American Veterinary Medical Colleges
Association of Independent Research Institutes
Association of Public and Land-grant Universities
Association of Research Libraries
Association of University Technology Managers
ASTRA, Alliance for Science & Technology Research in America
Auburn University
Battelle
Bay Area Council
Biophysical Society
Biotechnology Industry Organization
Boise State University
Boston University
Botanical Society of America
Brandeis University
Brown University
Business-Higher Education Forum
California Institute of Technology
California Polytechnic State University
Carnegie Mellon University
Cary Institute of Ecosystem Studies
Case Western Reserve University
Center for Policy on Emerging Technologies
Clemson University
Coalition for Aerospace and Science
Coalition for National Science Funding
Coalition for National Security Research
Colorado School of Mines
Colorado State University
Columbia University
Computing Research Association
Consortium for Ocean Leadership
Consortium of Social Science Associations
Cornell University
Council of Graduate Schools
Council of Scientific Society Presidents
Council on Competitiveness
Council on Governmental Relations
Crop Science Society of America
Delaware State University
Duke University
Earthquake Engineering Research Institute
East Carolina University
Ecological Society of America
EDUCAUSE
Emory University
Energy Sciences Coalition
Entomological Society of America
EPICenter Memphis
FASS
Federation of American Societies for Experimental Biology
Federation of Associations in Behavioral and Brain Sciences
Florida State University
Foundation for Science and Disability
Genetics Society of America
Geological Society of America
George Mason University
Georgia Institute of Technology
Georgia Regents University
Georgia Research Alliance
Georgia State University
Google
Greater Boston Chamber of Commerce
Greater Madison Chamber of Commerce
Harvard University
Hawaii Academy of Science
Hepatitis B Foundation
Hewlett-Packard Company
Human Factors and Ergonomics Society
IBM
Idaho Academy of Science and Engineering
IEEE-USA
Indiana University
Infineon Technologies Americas Corp.
Information Technology Industry Council (ITI)
Innovation Associates
Institute of Food Technologists
Intel Corporation
International Economic Development Council
International Society for Educational Planning
International Society for the Systems Sciences
International Technology and Engineering Educators Assn.
Iowa State University
IPC - Association Connecting Electronics Industries
Jefferson Science Associates LLC
Kansas State University
Kent State University
Kentucky Academy of Science
Lehigh University
Linguistic Society of America
Louisiana Tech University
Louisiana State University
Lowell Observatory
Maine State Chamber of Commerce
Massachusetts Institute of Technology
Materials Research Society
Mathematical Association of America
Michigan State University
Michigan Technological University
Micron Technology Inc
MN-SBIR
Montana State University
National Alliance for Eye and Vision Research
National Association of Colleges and Employers
National Association of Geoscience Teachers
National Association of Graduate-Professional Students
National Association of Marine Laboratories
National Center for Science Education
National Center for Technological Literacy- Museum of Science
National Coalition for Food and Agricultural Research
National Council for Science and the Environment
National Defense Industrial Association
National Ground Water Association
National Science Education Leadership Association
National Science Teachers Association
New Mexico State University
New York University
North Carolina Academy of Science
North Carolina State University
North Dakota State University
Northeastern University
Northern Illinois University
Ohio University
Oklahoma Academy of Science
Oklahoma State University
ON Semiconductor
ONAMI
Oregon State University
Pace University
Parapsychological Association
Penn State University
Phiston Technologies, Inc.
Population Association of America
Portland State University
Poultry Science Association
Princeton University
Qualcomm
Rensselaer Polytechnic Institute
ResearchAmerica
Rice University
Rochester Institute of Technology
Rutgers, the State University of New Jersey
SAGE
Semiconductor Equipment & Materials International (SEMI)
Semiconductor Industry Association
Semiconductor Research Corporation
Sigma Xi
SIlicon Valley Leadership Group
Small Business Technology Council
Society for In Vitro Biology
Society for Industrial and Applied Mathematics
Society for Industrial and Organizational Psychology
Society for Neuroscience
Society of the Study of Evolution
Society of Toxicology
Soil Science Society of America
South Dakota School of Mines & Technology
South Dakota State University
Southeastern Universities Research Association
Southern Illinois University System
SPIE, the international society for optics and photonics
SRI International
SSTI
Stanford University
State University of New York
Stillwater Chamber of Commerce
Stony Brook University
Supporters of Agricultural Research Foundation
Syracuse University
Task Force on American Innovation
Technology Association of Georgia
TechVision21
Texas A&M University
Texas Instruments Incorporated
Texas Tech University
The Coalition for the Life Sciences
The College of William and Mary
The Electrochemical Society
The Industrial Research Institute
The Johns Hopkins University
The New England Council
The Ohio State University
The Optical Society
The Procter & Gamble Company
The Science Coalition
The University of Alabama at Birmingham
TIES - Teaching Institute for Excellence in STEM
Tri-City Development Council – Tri-Cities, WA
Tufts University
University Economic Development Association
UNAVCO
United for Medical Research
Universities Research Association
University at Buffalo, State University of New York
University City Science Center
University Corporation for Atmospheric Research
University of Alaska
University of Alaska Fairbanks
University of Arizona
University of Arkansas
University of Arkansas at Little Rock
University of California System
University of California, Berkeley
University of California, Davis
University of California, Irvine
University of California, Los Angeles
University of California, Merced
University of California, Riverside
University of California, San Diego
University of California, San Francisco
University of California, Santa Barbara
University of California, Santa Cruz
University of Central Florida
University of Cincinnati
University of Colorado at Colorado Springs
University of Colorado Boulder
University of Colorado Denver
University of Colorado, Anschutz Medical Campus
University of Connecticut
University of Delaware
University of Florida
University of Georgia
University of Hawaii
University of Illinois
University of Illinois at Chicago
University of Illinois at Urbana-Champaign
University of Iowa
University of Kansas
University of Louisville
University of Massachusetts Amherst
University of Maryland
University of Michigan
University of Minnesota
University of Mississippi
University of Missouri System
University of Nebraska
University of Nevada, Reno
University of New Hampshire
University of New Mexico
University of North Carolina at Chapel Hill
University of North Carolina System
University of North Carolina Wilmington (UNCW)
University of North Dakota
University of Notre Dame
University of Oklahoma
University of Oregon
University of Pennsylvania
University of Pittsburgh
University of Rochester
University of South Dakota
University of South Florida
University of Southern California
University of Tennessee
University of Toledo
University of Vermont
University of Virginia
University of Washington
University of Wisconsin System
University of Wisconsin-Madison
University of Wisconsin-Milwaukee
University of Wyoming
Utah State University
Van Fleet & Associates
Vanderbilt University
Vermeer Corporation
Washington State University
Washington State University, Tri Cities
Washington University in St. Louis
Wayne State University
West Virginia University
Western Massachusetts Economic Development Council
Western Michigan University
Wichita State University
Woods Hole Oceanographic Institution
Yale University

The CHAIRMAN. Thank you, Dr. Wing.
Dr. Atkinson.

STATEMENT OF DR. ROBERT D. ATKINSON, PRESIDENT, INFORMATION TECHNOLOGY AND INNOVATION FOUNDATION

Dr. ATKINSON. Thank you. Good morning, Chairman Thune, Ranking Member Peters, and members of the Committee. It's a pleasure to come before you today to talk about why we need to reauthorize COMPETES.

It's no longer enough to just fund scientific research, although I agree with the two prior panelists, we need to do more, and better. But, what we need in any system is innovation. And innovation is really not just about the amount of money, but the efficiency by which knowledge is transferred into the economy. And we can do a better job of that. And that is a lot of the focus of COMPETES.

There's a second urgency to doing this, though, and that's that, in the last decade or so, other nations have really ramped up their game—their engineering and science capabilities, their ability to take U.S. knowledge and commercialize it for competitive advantage. We're now in a system where if the U.S. doesn't commercialize its own R&D, a competitor nation likely will.

Why isn't it just enough to fund research? It is important to fund research, but it's not enough. Over the last decade or so, science policy scholars have really come to a much deeper understanding that there are an array of failures that make it hard sometimes to take discovery and end up with innovation. And, unfortunately, our system today is still fundamentally grounded in what science policy scholars call "the linear model." We fund research up front, and we hope something good comes out the end. Oftentimes, it does, but, too often, it doesn't. For example, if you look at the NSF budget, only 2 percent of the NSF budget goes to programs focused on industry/university partnerships, despite the fact that the programs that NSF operates in this area have been widely reviewed as being excellent programs that produce good science and good innovation for the marketplace.

Also, the other problem we have is, we have a vast difference in commercialization performance between universities, between our Federal labs. Some are very good, and some, frankly, are not that good. If you look just, for example, at the amount of money that industry gives for university research, you see a big divergence between the top-ranked university, Duke, at around 18 percent of their funding for research comes from industry, to a university like Brown, which gets less than 1 percent. So, we can do better. And COMPETES has a number of—I know you've been considering a number of roles that will move us in that direction. Let me just quickly mention a few that I think are important.

One is the Senate Manufacturing Universities Act, which would designate 25 manufacturing universities and fund them to focus more on manufacturing education and manufacturing research partnerships.

Second, we need more focus and more funding for commercialization. And this could be done in a budget-neutral way; for example, as the Startup America Act does, where it sets aside a very small portion of Federal extramural research budgets to go for commer-

cialization programs, commercialization grants, et cetera. My one suggestion for there would be to make sure that that program be expanded to include State commercialization programs. Every one of your states has a State-funded commercialization entity that does very, very good work. I think they should be eligible for these kinds of programs.

There are a host of other areas. One would be on reforming and expanding the Small Business Innovation Research Program, the SBIR Program. There is a proposal—Senator Coons and Senator Gardner have a proposal to expand—allow awardees to expend up to $35,000 of their Phase 2 awards on commercialization-oriented activities. Again, it's one thing to do research, but if you can take a small amount of that money and let them think about commercialization of that, we'd be more likely to get that in the marketplace.

Another area that we highlight is the importance of the NIST Manufacturing Extension Partnership Program, which is a very effective program at centers around the country, with private-sector engineers operating it. So, besides increasing the funding there, I would argue we need to change the match requirement, which is now 2-to-1, to a 1-to-1 match.

Another area we believe is important is the area of high-performance computing. ITIF issued a report recently that showed that, while we had been leading in HPC, and probably still lead, that lead is in threat, because many other countries—China being one of them—are putting enormous amounts of money and resources in supporting HPC research. That's why we support the President's National Strategic Computing Initiative, and urge Congress to fund that.

Finally, STEM talent. Clearly, STEM education and high-skill immigration for STEM workers is going to be critical. One thing I would encourage the Committee to consider is supporting the President's initiative on computer science education. CS education is critical to our future. Only about 25 percent of U.S. high schools even teach computer science today. And that, frankly, is a travesty. And so, Congress can take a key role in trying to turn that around.

Thank you very much.

[The prepared statement of Dr. Atkinson follows:]

PREPARED STATEMENT OF DR. ROBERT D. ATKINSON, PRESIDENT, INFORMATION TECHNOLOGY AND INNOVATION FOUNDATION

Good morning, Chairman Thune, Ranking Member Nelson, and members of the Committee; thank you for inviting me to share the views of the Information Technology and Innovation Foundation (ITIF) on the reauthorization of the America COMPETES Act. The Information Technology and Innovation Foundation is a nonpartisan think tank whose mission is to formulate and promote public policies to advance technological innovation and productivity internationally, in Washington, and in the states. Recognizing the vital role of technology in ensuring prosperity, ITIF focuses on innovation, productivity, and digital economy issues. ITIF has long been involved in the policy areas COMPETES addresses, including science policy, tech transfer, and STEM (science, technology, engineering, and math) education. I very much appreciate the opportunity to comment on these issues today. I also want to mention that I appreciate having been invited by the Committee to a prior roundtable on COMPETES Reauthorization and want to commend the Committee for having such an open and inclusive process for receiving input on the bill from a wide range of stakeholders.

Why America Needs COMPETES Act Reauthorization

Reauthorization of COMPETES is crucial to the well-functioning of the U.S. innovation system. It is no longer enough to simply fund scientific and engineering research and hope it gets translated into commercial results with the U.S. economy. This is true for two key reasons. First, for many decades after the Soviets launched Sputnik in 1957 the U.S. Government invested considerable sums into research and development (R&D). And if some of that research "sat on shelf" or lay largely unread in a journal we could rest easy in knowing that at least some of it got into new technology-enabled products, processes, and services. But because of budget limitations we no longer have that luxury. In fact, according to the National Science Foundation (NSF), Federal funding for R&D in 2016 as a share of GDP will be the lowest it has been since the Russians launched Sputnik, almost 60 years ago. To restore Federal R&D to GDP ratio to levels averaged in the 1980s, the Federal Government would have to invest $65 billion more per year. These lower funding levels mean we need much more efficiency in how we transfer discovery to commercialization within the U.S. economy if we are to avoid a reduction in the pace of innovation.

Second, for many decades after WWII the U.S. innovation system was unique in that few other nations had a well-established science and engineering system that could generate, absorb and commercialize discoveries. Moreover, a less interconnected globe limited internationally the geographic spillover of U.S. discoveries. This meant that much of the benefits of the scientific and engineering research the Federal Government funded stayed in the United States to the benefit of our economy as firms used the discoveries to build globally competitive positions. But as we point out in our book *Innovation Economics: The Race for Global Innovation Advantage,* over the last two decades many nations have put in place much more sophisticated innovation systems (*e.g.,* funding research universities, supporting STEM education, crafting R&D tax incentives) to the point now where they are more easily able to take advantage of the knowledge discoveries stemming from U.S. investment in R&D. Now, if the United States does not commercialize its own R&D, a competitor nation likely will.

In short, given the decline in R&D funding and the dramatic increase in technological competencies of our economic competitors, we can no longer simply hope that some of the R&D funding ends up actually being used. This is why the COMPETES reauthorization is so important because it focuses on improving the efficiency of the process by which federally-funded knowledge creation leads to actual innovation and U.S. jobs.

At one level this is good news. Improving the efficiency of the scientific and engineering research system can provide significant benefits at a lower budgetary impact than increasing funding without improving the efficiency. But continuing to underfund research while also not improving the efficiency of the system with the kinds of measures in COMPETES is a recipe for underperformance. And to be clear doing both is ideal: more Federal funding for R&D and a better commercialization and tech transfer system.

Why Federal R&D Policy Needs to Go Beyond Simply Funding Research

Before discussing particular provisions that I believe are needed, it's important to briefly discuss why these kinds of provisions are needed. Won't the knowledge created by Federal R&D funding naturally get commercialized? Won't the institutions involved, especially universities and Federal labs, naturally want to transfer technology? Why should Federal policy and funds be focused on this? The short answer is that the process of innovation from discovery to application is usually not an easy one, despite what Vannevar Bush suggested when he penned *Science: The Endless Frontier* 70 years ago. As more scholarship about the nature of innovation has been developed it has become clear that the process of innovation is much more complicated and subject to many failures and problems that require a more strategic role for government along the entire innovation lifecycle.

Yet, the current Federal system of funding R&D still is based on a "linear model" of research that simply assumes that basic research will get transferred into new products and services. For example, only 2 percent of the NSF budget goes to programs focused on the development and commercialization of knowledge through industry-university partnerships. Given institutional inertia, coordination and communication challenges, and lack of funding for proof of concept research, overcoming the "valley of death" between basic research and its real world application is often the most difficult part of the innovation process. If this jump is not able to be made, the benefits of the money spent on knowledge discovery will be more limited.

The roadblocks and challenges are many. The culture and reward system in many universities and labs is oriented to research, not application or transfer. This is re-

flected by the very dramatic difference in performance of U.S. universities when it comes to technology commercialization, whether it's enabling start-up companies or transferring technology to existing companies. The seminal report *Innovation 2.0: Reinventing University Roles in the Knowledge Economy* finds that while the best universities and colleges in America are world class when it comes to transferring knowledge, many are not and need to learn from and copy the best practices of the leaders. To be sure, compared to even five years ago, America's universities and colleges appear to be doing a better job of technology commercialization, but there is still a wide variance between them in terms of the focus on and effectiveness of commercialization. One measure of this is the share at which industry funds university academic research. Of the top 30 U.S. research universities, the percentage ranges from 17.8 percent at Duke and 13.6 at MIT to just 0.9 percent at Brown and 2.2 percent at Johns Hopkins. There is also significant variation by state, with the U.S. average at 5.4 percent, but North Carolina at 9.8 percent, Kansas at 7.8 percent, New York and Ohio at 7.7 percent, but Michigan at just 3.1 percent. Moreover, the share has been falling, from 7.4 percent in 1999 to 5.4 percent now. We need more universities and colleges to be closer to national best practices. This means, for example, more universities should recognize patenting and commercialization success as part of tenure consideration, something which is currently the case at less than one-quarter of America's top 200 universities. More universities should also allow faculty members to suspend their tenure so that they may pursue commercialization opportunities. More universities should also define an entrepreneurial leave policy for undergraduate and graduate students in which students could retain full-time student status for several years while launching their own company.

Even if institutions are focused on transferring technology, there are multiple hurdles, some of them from Federal regulation, others stemming from market failures like the high costs of information search. Moreover, there is significant complexity of modern technology-based industry structures from the fact that the scope of technology systems and hence the number of supplier industries has grown as technological complexity has expanded, creating major information and coordination market failures that lead to poorly functioning innovation systems. On top of that there is a second "valley of death" in the process of scaling up prototypes where promising discoveries can flounder, never making it to final production. In part this is because many companies—in part because of pressures from capital markets—have become more risk adverse, preferring, in the terms of Harvard's Clay Christensen, sustaining, rather than disruptive, innovation.

Congress has a long tradition of legislation focused not just on funding R&D but on improving the functioning of the U.S. R&D system. In 1980, it passed the Stevenson-Wydler Technology Innovation Act and the Bayh Dole Act. The latter legislation permitted inventors receiving Federal funds for research to own the invention rights. The former legislation stated that "technology and industrial innovation are central to the economic, environmental, and social well-being of citizens of the United States." In 1982, the Reagan administration supported the establishment of the Small Business Innovation Research Program (which required Federal agencies to allocate a small share of their R&D budgets to small business research projects). Congress also passed a number of important laws, including the Federal Technology Transfer Act of 1986, National Defense Authorization Act for FY 1991, the Technology Transfer Improvements and Advancement Act, and the Technology Transfer Commercialization Act. Perhaps most important was the Omnibus Trade and Competitiveness Act of 1988. Among other things, the Act created the Technology Administration in the Department of Commerce, reorganized the National Bureau of Standards into the National Institute of Standards and Technology, and created a number of programs to help industry with innovation, including the Malcolm Baldridge Quality Award and the Boehlert Rockefeller State Technology Extension Program.

Recommendations for COMPETES Reauthorization

There are many components of COMPETES that will have important beneficial impacts on the U.S. innovation system. Let me suggest a few areas that I believe are especially important.

One focus of COMPETES is rightly on reducing the barriers and improving the incentives for commercialization. In this respect, small changes and modest amounts of funding can have an outsized impact. For example, ITIF partnered with the Center for American Progress and the Heritage Foundation to issue a report *Turning the Page: Reimaging the National labs in the 21st Century Innovation Economy.* The report included a number of low- or no-cost recommendations that would give the labs more flexibility and more incentives to see that more of their path-breaking research gets transferred to and used by companies in the United States. These in-

cluded steps such as allowing labs to use flexible pricing for user facilities and special capabilities, adding weight to technology transfer in the expanded Performance Evaluation Management Plan, and removing top-down accounting rules to give labs more flexibility.

Similarly, there are a number of steps that can be taken to better link American universities with industry. For example, it is striking that the United States lags so many nations in terms of the linkages between universities and industry. In fact, as a share of GDP among the 39 OECD nations, the United States ranks just 27th in industry funding of university R&D, as ITIF writes in its report *University Research Funding—Still Lagging and Showing No Improvement.*

One way to remedy this would be to provide support and incentives for universities to update the curriculum and approach of university engineering programs to better prepare engineers for careers in innovation and advanced manufacturing and better link university research to industry needs. Senators Coons, Graham, Ayotte, Gillibrand, Baldwin, Kirk, and Franken have partnered to introduce legislation, endorsed by 26 House co-sponsors, called The Manufacturing Universities Act, which would designate 25 "Manufacturing Universities" and provide them with grants of up to $5 million a year for four years to reshape their engineering programs with a stronger focus on advanced manufacturing. The resources would help universities promote their manufacturing engineering programs to attract more students into the field, promote more inter-disciplinary education, and allow engineering programs to purchase essential equipment to support hands-on, project-based learning, and working more on collaborative research projects with industry.

We also need to establish stronger university entrepreneurship metrics, collecting better data regarding commercialization, including: new business starts and spin-offs of new companies by faculty and students from universities, the amount of industry funding of R&D, patents issued, etc. Congress should direct the National Science Foundation to develop and implement metrics by which universities report such information annually.

In addition, we need more funding for commercialization activities. One way to do this would be to establish a set-aside program from Federal extramural research for commercialization grants. In the House, the Startup America Act 3.0 (H.R. 714) introduced by Loretta Sanchez, Gerald Connolly, and Jared Polis, would set aside 0.15 percent of Federal agencies' extramural research budgets to offer both (1) "commercialization capacity building grants" to institutes of higher education pursuing specific innovative initiatives to improve an institution's capacity to commercialize faculty research and (2) "commercialization accelerator grants" to support institutions of higher education pursuing initiatives that allow faculty to directly commercialize research in an effort to accelerate research breakthroughs.

However, we recommend that any such program be expanded to include state technology commercialization programs (either state governments or non-profit agencies they designate) as eligible recipients. Many states and regions fund their own technology transfer and commercialization efforts between their universities and the private sector. Federal funds could match these efforts at some percentage level to bolster their impact. Regardless of this, it will be important to expand funding for the Regional Innovation Program which prior COMPETES legislation authorized to "encourage and support the development of regional innovation strategies," which focus on commercialization, entrepreneurship, and startups. There is great demand for this program from programs all around the Nation. In 2015, $15 million in grants were awarded. The program should be significantly expanded, to perhaps $75 million.

In a similar manner, a number of organizations throughout the United States are experimenting with novel approaches to bolster technology transfer from universities (and national laboratories) to industry and to accelerate the commercialization of university-developed technologies. COMPETES should support these types of novel approaches by including $5 million to fund experimental programs exploring new approaches to university and Federal laboratory technology transfer programs. The program should be managed by the Department of Commerce's Office of Innovation and Entrepreneurship. Organizations would apply for the grants and winning proposals would be selected on criteria such as: (1) how innovative they are in demonstrating a new model; (2) recent documented success of their program; and (3) willingness to publicly disclose best practices learned from their programs and teach other U.S. organizations.

In addition, Congress should increase funding for the kinds of programs that are more focused on supporting university-industry research partnerships. While this is ideally achieved as part of an overall increase in Federal R&D funding, it could be done in a revenue neutral way. In particular, the Engineering Research Center (ERC) and the Industry & University Cooperative Research Center (IUCRC) pro-

grams should receive a larger share of the overall NSF budget. There are 19 ERCs and 76 Industry/University Cooperative Research Centers, but their funding is quite modest. These programs can be quite effective at supporting innovation. For example, I/UCRC produces substantial cost savings for companies. When private companies conducted R&D projects through the I/UCRC partnership rather than in-house, they saved an average of $700,000 per project in 2014—up from $500,000 in 2012—thereby freeing up resources to be put to other, more effective, uses.

COMPETES should also support the NSF I-Corps program, which is an innovative effort to improve the "transmission belt" of transforming knowledge into innovation. As Senators Fischer and Coons have proposed, I-Corps should be established in statute, and authorized at least through 2020, and Congress should consider increasing its funding and expanding its availability to other Federal agencies, including the NIH, DOD, DOE and USDA.

In addition, crowdsourcing and citizen science can empower individuals and organizations to participate in the scientific process by undertaking discrete, independent tasks to solve problems. For example, Cornell University's eBird project enlists people to record and report birds they say in order to improve scientific understanding of bird populations. Legislation proposed in the *Crowdsourcing and Citizen Science Act of 2015* would encourage and increase the use of crowdsourcing and citizen science methods within the Federal Government to advance and accelerate scientific research, literacy, and diplomacy. The Act would authorize agencies to use open-innovation tools to advance their missions, encourage the heads of agencies to work cooperatively on crowdsourcing or citizen science projects, increase inter-agency coordination, and strengthen the public's role as an active partner and meaningful contributor to the U.S. innovation engine.

Congress should also reform The Small Business Innovation Research (SBIR) program. Despite the fact that the SBIR program accounts for just over 3 percent of the Federal extramural R&D budget, a recent ITIF study, *The Demographics of Innovation in the United States,* found that 60 percent of innovations included in the study created by companies with fewer than 25 employees utilized public grants through SBIR. Yet despite its strengths, there are several programmatic reforms that could make SBIR an even stronger engine of commercialization activity.

First, SBIR Phase II awardees should be permitted to expend up to 5 percent of their Phase II funding on commercialization-oriented activities, such as market validation, IP protection, market research, and business model development, as Senators Coons, Gardner, and Gillibrand propose in the *Support Startup Businesses Act.* In the House, legislation similar in intent to foster commercialization activities has been proposed in an amendment to SBIR reauthorization legislation submitted by House Small Business Committee Ranking Member Nydia Velázquez. In addition, Congress should call on Federal agencies with SBIR/STTR programs to standardize their commercialization data collection practices (whether around the DOD or new SBA model). The data is now collected individually by each agency in their own form and with different requirements, which both makes it more difficult for small businesses to comply or for useful insights to be gleaned from the data.

In addition, NIST's Hollings Manufacturing Extension Partnership (MEP) plays in important role in innovation. As ITIF writes in *International Benchmarking of Countries' SME Manufacturing Technology Support Programs,* a number of countries, across the developed and developing world alike, have manufacturing extension programs whose mission is to assist small to medium-sized enterprise (SME) manufacturers with implementing advanced manufacturing and quality processes and undertaking innovative new product development efforts. These programs: (a) promote technology adoption by SMEs; (b) conduct audits to identify opportunities for improvement in their manufacturing and operational processes; (c) support technology transfer, diffusion, and commercialization; (d) perform research and development in direct partnership with SMEs, and/or providing access to research labs; and (e) engage SMEs in collaborative research and development and/or technology-specific consortia. In the United States, client surveys indicate that MEP centers create or retain one manufacturing job for every $1,570 of Federal investment, one of the highest job growth returns out of all expenditures of Federal funds in the United States.

As a result, it is important to increase support for NIST's Hollings Manufacturing Extension Partnership (MEP), moving beyond the $130 million in funding the program received in FY 2016 (and even the current Congressionally authorized amount of $165 million in funding). As Senators Kelly Ayotte and Chris Coons have called for in *The Manufacturing Extension Partnership Improvement Act of 2016,* MEP funding should be increased to $260 million annually and the program authorized through 2020. In addition, a key to improving the effectiveness of the MEP program is to modify the cost share. Currently, after five years, centers are required to raise

2 dollars of non-federal funds for every Federal dollar received. This relatively high ratio (higher than other Federal matching grant programs), makes it harder for centers to fulfill their public purpose and respond to market failures. In particular, it makes it harder for centers to help start-ups and very young manufacturers and to support workforce training, export promotion, technology transfer efforts, and energy efficiency and environmental improvement. In addition, it makes sense to experiment with sectoral expansion of the MEP program into industries such as construction. As ITIF notes in a new report *Think Like an Enterprise: Why Nations Need National Productivity Strategies,* the measured productivity growth of the U.S. construction industry has actually been negative in recent decades. This is not because there are not technologies, tools, and practices the industry can use to get more productive. Much of the problem stems from the fact most construction firms are very small and lack access to information about how to use these technologies effectively. An MEP extension could play an important role in remedying this.

High-performance computing (HPC) should be another area of focus. HPC refers to supercomputers and other technical computing systems that, through a combination of processing capability and storage capacity, can rapidly solve difficult computational problems across a diverse range of scientific, engineering, and business fields. HPC represents a strategic, game-changing technology with tremendous economic competitiveness, science leadership, and national security implications. The United States has long led the world in the development and adoption of high-performance computing systems, but as ITIF writes in *The Vital Importance of High-Performance Computing to U.S. Competitiveness,* U.S. leadership in high-performance computing is increasingly under threat as a growing number of nations, including China, the European Union nations, Japan, and Korea, have introduced concerted national strategies and announced significant investments in developing next-generation HPC systems. To safeguard continued U.S. HPC leadership, in July 2015 the Obama administration announced the National Strategic Computing Initiative (NSCI), a coordinated Federal strategy for HPC research, development, and deployment and defines a multiagency framework for furthering U.S. economic competitiveness and scientific discovery through orchestrated HPC advances. Continued leadership in high-performance computing will require a steady, stable, robust, and predictable stream of funding. To ensure the NSCI can meet its targeted objectives, Congress should authorize and appropriate NSCI funding levels as requested in the administration's FY 2017 budget for FY 2017 and future years, with Congress funding NSCI and related high-performance computing initiatives at a level of at least $325 million per year over at least the next five years.

Finally, increasing the supply of STEM talent is another critical area COMPETES legislation rightly focuses on. Despite what some have argued, as ITIF has shown in numerous reports, there is a shortage of STEM workers, including in computer science.

A part of the solution will be increased STEM immigration. As a recent report by ITIF on the demography of U.S. innovation demonstrates, more than one-third (35.5 percent) of U.S. innovators were born outside the United States, even though this population makes up just 13.5 percent of all U.S. residents. Another 10 percent of innovators were born in the United States but have at least one parent born abroad. Immigrant innovators also are better educated on average than native-born innovators, with over two-thirds holding doctorates in STEM subjects.

Making it easier for more immigrants with STEM graduate degrees to become U.S. permanent residents will be important for driving innovation. Congress should also reform the EB–5 visa program which enables foreign investors to obtain a visa if they invest in a domestic enterprise and create or preserve at least 10 full-time jobs and invest at least $1 million. But many EB–5 projects simply displace projects that would have occurred anyway. Commercial property development does nothing for competitiveness or innovation. There is no real net benefit from allowing someone to obtain a visa by investing in a donut shop, golf course, or apartment building. These activities would be developed naturally by the market in the United States if there is in fact a demand for them. There is no shortage of entrepreneurs or capital for these kinds of non-traded business activities. In contrast, foreigners who want to immigrate to the United States to establish companies, particularly technology-based ones, in traded sectors (*e.g.,* manufacturing) are much more likely to represent a net addition to the economy rather than launch a business that just crowds out domestic activity. Therefore, Congress should consider narrowing and targeting the EB–5 program to be more focused on building technology-based businesses.

We also face a challenge in expanding the domestic pool of STEM talent, particularly among women and minorities. In ITIF's study, women represent only 12 percent of U.S. innovators. This constitutes a smaller percentage than the female share

of undergraduate degree recipients in STEM fields, STEM Ph.D. students, and working scientists and engineers. Minorities born in the United States are also significantly underrepresented: U.S.-born minorities (including Asians, African Americans, Hispanics, Native Americans, and other ethnicities) make up just 8 percent of U.S.-born innovators. These groups constitute 32 percent of the total U.S.-born population. Despite comprising 13 percent of the native-born population of the United States, African Americans comprise just half a percent of U.S.-born innovators.

One reason to support robust funding for university research is that it enables universities to train more graduate STEM students. As ITIF has found, innovators in the United States are experienced and highly educated, and most hold advanced degrees in science and technology fields: four-fifths of innovators possess at least one advanced degree, and 55 percent have attained a Ph.D. in a STEM subject. Half of innovators majored in some form of engineering as an undergraduate, and more than 90 percent majored in a STEM subject as an undergraduate.

One path to expanding the number of highly qualified STEM workers is to expand the number of STEM-focused high schools. There are currently about 100 of these high schools in America, like Thomas Jefferson in Northern Virginia or Montgomery Blair in Montgomery County (which just won the national Science Bowl competition). These public STEM high schools provide students who have an interest and aptitude for STEM subjects with the opportunity to focus more intently on STEM subjects. They have also have been proven to be effective in helping minorities and students from socio-economic disadvantaged areas gain a high-quality STEM education. Given their effectiveness, we should set a goal to double the number of STEM high schools. Congress could do that by establishing a modestly funded challenge grant program that would allow states and cities to receive modest grants to help plan and establish new STEM high schools.

Congress should also do this for the establishment of new tech-focused universities, such as Olin College in Massachusetts or The Harrisburg University of Science and Technology in Harrisburg, Pennsylvania, or new types of STEM curriculum and programs at existing universities. One way to do this would be to expand support for NSF's Transforming Institution Grants program.

Another way the Federal Government could encourage STEM education is by providing prizes to colleges and universities that do best at retaining STEM students. This matters especially because 60 percent of those who enter college intending to pursue a STEM degree fail to graduate with one. Congress should authorize the National Science Foundation to establish a prize funds program to award to colleges and universities that have dramatically increased the rate at which their freshmen STEM students graduate with STEM degrees and that can demonstrably sustain that increase over five years.

In addition, the Federal Government should also require increased transparency from colleges and universities regarding the number of STEM applicants, prospective majors, and their retention rates in STEM subjects. There is some evidence that colleges and universities, especially state universities, could enroll more STEM students, but for a variety of institutional reasons do not do so. Better data regarding applications and retention will shed light on just how much of a problem this is.

Finally, one key factor in producing more PhD degrees in STEM, especially by U.S. residents, is the ability to support doctoral fellowships. But as Harvard's Richard Freeman notes, the number of NSF graduate research fellowships awarded per thousand of college students graduating with degrees in science and engineering went from over seven in the early 1960s to just over two in 2005. Today, the same number of NSF graduate research fellowships are offered per year as in the early 1960s, despite the fact that the number of college students graduating with degrees in science and engineering has tripled. But rather than simply expand funding for the NSF Graduate Research Fellowship program (funded at $102 million), Congress should create a new NSF-industry PhD fellows program. Currently the program provides up to three years of support over a five-year period and supports approximately 3,400 students per year at $40,500 per year. The new NSF-industry program would work by enabling industry to fund individual fellowships of $20,250 with NSF to match industry funds dollar for dollar. Congress should allocate an additional $21 million to a joint industry-NSF STEM PhD fellowship program. This would allow NSF to support an additional 1,000 graduate fellows.

In summary, COMPETES reauthorization is an important step to take to ensuring that America does not lose its lead in innovation. Thank for you inviting me to testify before the Committee today.

The CHAIRMAN. Thank you, Dr. Atkinson.

Dr. Munson.

STATEMENT OF DAVID C. MUNSON, JR., ROBERT J. VLASIC DEAN OF ENGINEERING, COLLEGE OF ENGINEERING; PROFESSOR, DEPT. OF ELECTRICAL ENGINEERING AND COMPUTER SCIENCE, UNIVERSITY OF MICHIGAN

Dr. MUNSON. Thank you to the Chairman and Ranking Member and members of the Committee. I appreciate the invitation to speak with you today about topics to help ensure Americans in competitiveness and global leadership innovation.

I'm currently the Dean of Engineering at the University of Michigan Ann Arbor, a professor in the Department of Electrical Engineering and Computer Science, and the co-founder of a startup company that works in the area of tomographic, or CT, imaging.

I would like to talk to you today about just a few topics critical to the higher education research enterprise. At its core, the U.S. investment in and commitment to research should be considered a strategic national asset and treasure. American higher education still has no peer in the development of talent, although other nations, as we've heard, are catching up. Our main competitive advantage remains in the area of creativity and innovation. American society fosters an out-of-the-box unencumbered spirit, where nearly anything is deemed to be possible. This is exactly the mentality that creates a robust STEM pipeline for the conduct of high-impact federally-funded research. And, in turn, Federal research dollars facilitate the education and training of an especially creative STEM workforce.

Research, in many ways, is a creative process with outcomes that are impossible to predict. Research has led us to a wide range of stunning discoveries and inventions, whether it was the cure to a disease or the invention of the Internet. The Federal Government has and needs to continue to play the key role in enabling the creative research process through funding of fundamental research.

Research impact is translated through the innovation ecosystem. This ecosystem is complex, requiring multiple partners to play a range of roles. The early phase of innovation is basic or fundamental research, a domain dominated by academic institutions and enabled by the resources and policies created primarily by the Federal Government.

Moving to the applied realm, there was a wide playing field, where academia, industry, and government all work to support translational research with an eye toward desired outcomes. Again, at this stage, Federal resources and policies are important enablers, with industry and angel investors also key at this stage of the innovation cycle. The Federal SBIR program is a vitally important vehicle for supporting translational research.

Moving into the final phase of development or deployment and implementation, the customer, whether it be industry or Federal Government, is the lead player, sometimes with the support of venture capital. Also, the Federal Government often plays an important policy role, especially with intellectual property, in appropriately enabling innovations to move forward.

In thinking about the innovation ecosystem, programs such as the NSF I-Corps are having a tremendous impact. Similar to

STEM pipeline programs, I-Corps is an important enabler and eye opener for faculty and often graduate students. On day one of the I-Corps program, startup teams are confronted with the importance of the marketplace, when teams are required to contact dozens of possible customers and receive their feedback. From personal experience, I can report that the startup process is grueling. The ideal technology with no market simply has no value. Fortunately, with positive role models and the encouragement and support of university and regional entrepreneurial ecosystems, the results can be amazing. The required passion and energy flows from the strong desire of our faculty and students to make a positive impact on the world. It is our job to enable and support their success through programs and policies.

Probably the greatest inefficiency in the Federal research system is caused by the low funding rates of many agencies. For example, at the NSF, the fraction of research proposals that are funded has slipped to about 20 percent. This means that faculty members are spending a huge fraction of their time writing proposals and also reviewing proposals of their colleagues, with a high probability that these proposals will not be funded. It is my experience, from 37 years in academia, that about one out of three research proposals is truly excellent and easily merits funding. To provide a funding rate consistent with this statistic, one might assume that it would be necessary to increase the annual NSF or other agency budget by over 50 percent to move from a 20-percent to a 33-percent funding rate. However, a smaller but still significant increase might buy much more than is apparent. One reason the NSF and other government agencies receive so many proposals is because the probability of funding is so low. When a proposal is not funded, the faculty member typically reworks the proposal and then resubmits it, or else creates a proposal on a different topic. This proliferation of research proposals is bogging down the system, causing a waste of time and resources, and is part of the reason for low funding rates. In a sense, we are running the research system at an inefficient operating point. In my opinion, it would be far more effective to fund the research agencies at a somewhat higher level, driving down the number of research proposals that are written and reviewed, in which case funding rates would rise and researchers would spend far more of their time actually doing research.

In closing, today's engineering students and faculty share a heartfelt passion to make a difference. Our faculty provides students with a firm grounding in fundamentals and also with the ability to learn, adapt, and create as they move through their careers. We must provide our faculty and students with the resources needed to explore and innovate. The Nation will be the beneficiary.

Thank you.

[The prepared statement of Dr. Munson follows:]

PREPARED STATEMENT OF DAVID C. MUNSON, JR., ROBERT J. VLASIC DEAN OF ENGINEERING, COLLEGE OF ENGINEERING; PROFESSOR, DEPT. OF ELECTRICAL ENGINEERING & COMPUTER SCIENCE, UNIVERSITY OF MICHIGAN

Good afternoon, Mr. Chairman, Ranking Member, and members of the Committee. Thank you for inviting me to speak with you today about topics to help ensure American competitiveness and global leadership in innovation. I currently am the Dean of Engineering at the University of Michigan, Ann Arbor, and am a Pro-

fessor in the Department of Electrical Engineering and Computer Science. I am also the co-founder of InstaRecon, a start-up that has developed and commercialized patented and patent-pending algorithms that reconstruct images from 2D and 3D tomographic, or CT, data 20 to 100 times faster than conventional methods for typical image sizes.

I would like to talk to you today about a range of topics critical to the higher education research enterprise. At its core, the U.S. investment in and commitment to research should be considered a strategic national asset and treasure.

First, I would like to start with the talent pipeline for STEM (Science, Technology, Engineering and Math). In order to continue to be the innovation leader that we are today, it is vital that our STEM population be sufficiently large and especially well educated. Both the size of the population and the quality of education should draw on the rich diversity of our Nation. Talent knows no boundaries; there are exceptional people throughout all demographics in the country. We know that opportunity does not present itself to everyone in equal measure to all that are deserving and capable. We must continue to address this issue, and expand our efforts to engage the future scientists and engineers of our Nation. Programs such as FIRST Robotics provide a vital link between fun and interesting engineering projects and the STEM disciplines that K–12 students are studying in school. Expanding efforts in education to provide students with context and relevance opens doors and is critical to our future. The opportunity to grow a more diverse STEM population relies on our ability to provide a broader range of students with an answer to the "so what" question when participating in STEM classes—students need to better understand why they should care about success in STEM disciplines during their K–12 studies.

Today, there exists a huge range of discrete investments aimed at addressing this challenge. The scale of this problem, however, is immense. Discrete investments are helpful, but such a pressing national issue would benefit from a more coordinated approach. As a nation, we should contemplate unified programs that will enable the challenge to be tackled more broadly, leveraging best practices and creating integrated partnerships between government, industry, and academia. Everyone wins if our Nation's STEM pool is more robust and diverse. A national network, utilizing a public/private partnership, could be contemplated to address this issue at scale. With such a network, federally-funded programs that currently have discrete "pipeline development" and/or "workforce development" programs could integrate into an existing national infrastructure, with each program playing a well defined and coordinated role, thereby producing a broader impact and reach. This would build on elements of the current model where individual programs have created independent solutions with limited scope and no ability to scale.

In reflecting on the capability of programs to have measureable impact, I believe there is some consensus about what works, and on key indicators that can be measured to make sure that programs are on track. The missing elements in this equation are the ability to share best practices across the Nation and to decide which organizations will tackle the big pieces and do so at scale. Of course, operating at scale will also require resources to assure the desired impact.

Demand for engineering and computer science graduates has greatly accelerated at the University of Michigan. I am hearing the same from peer institutions. Talent provides the ultimate competitive advantage. As the world becomes smaller and smaller through technology, and the labor cost differential between geographic regions narrows, talent will be *the* differentiating factor in economic competitiveness. Environments that can best develop their talent will have a significant competitive advantage in attracting and retaining cutting-edge industry.

American higher education still has no peer in the development of talent, although other nations are catching up in some ways. Our main competitive edge remains in the area of creativity and innovation. American society fosters an out-of-the-box, unencumbered spirit, where nearly anything is deemed to be possible. This is exactly the mentality that creates a robust STEM pipeline for the conduct of high-impact federally-funded research.

And, in turn, Federal research dollars facilitate the education and training of an especially creative STEM workforce. Research, in many ways, is a creative process, with outcomes that are impossible to predict. Research has led us to a wide-range of stunning discoveries and inventions, whether it was the cure to a disease or the invention of the Internet. The Federal Government has and needs to continue to play the key role in enabling the creative research process through funding fundamental research.

That said, it is important to also have a suite of programs that create strong links to industry and Federal customers (such as Department of Defense). These partners bring important research issues to academia in a variety of application areas. The National Network of Manufacturing Institutes (NNMI) is an excellent example of

such a program, bringing a diverse group of institutions together to identify, research and then implement solutions which are critical to advancing a domain of national strategic importance—manufacturing.

Historically, it has been a challenge to reach a level of trust with industry research partners sufficient to permit sharing of proprietary ideas, which can enable progress on topics that really matter. "Trusted conversations" are essential to enabling research and allowing researchers to have impact. Engaging in these conversations requires striking a balance between openness and a collaborative spirit and assuring that competitive advantage is not compromised. The University of Michigan has been successful in managing this tradeoff by investing time and effort in creating strong links with industry partners that are outcome oriented. Trust is an essential ingredient in these public-private partnerships as evidenced in the ongoing research program of the University of Michigan Mobility Transformation Center, which has a consortium of more than 60 companies that are supplementing Federal and State of Michigan research dollars in the area of connected and autonomous transportation.

Research impact is translated through the innovation ecosystem. This ecosystem is complex, requiring multiple partners to play a range of roles. The early phase of innovation is basic or fundamental research, a domain dominated by academic institutions and enabled by the resources and policies created primarily by the Federal Government. Moving to the applied realm, there is a wide playing field, where academia, industry and government must partner to support translational research with an eye toward desired outcomes. Again, at this stage, Federal resources and policies are important enablers, with industry and angel investors also key at this stage of the innovation cycle. The Federal SBIR program is a vitally important vehicle for supporting translational research. Moving into the "final" phase (development and deployment/implementation), the customer, be it industry or the Federal Government, is the lead player, sometimes with the support of venture capital. Also, the Federal Government often plays an important policy role, especially with intellectual property, in appropriately enabling innovations to move forward.

In thinking about the innovation ecosystem, programs such as the NSF ICorps, are having a tremendous impact. Similar to STEM pipeline programs, ICorps is an important enabler and eye-opener for faculty and (often) graduate students. On Day 1 of the ICorp program, start-up teams are confronted with the importance of the marketplace, when teams are required to contact dozens of possible customers and receive their feedback. From personal experience, I can report that the start-up process is grueling. The "ideal" technology with no market simply has no value. Fortunately, with positive role models and the encouragement and support of university and regional entrepreneurial ecosystems, the results can be amazing. The required passion and energy flows from the strong desire of our faculty and students to make a positive impact on the world. It is our job to enable and support their success through programs and policies.

Probably the greatest inefficiency in the Federal research system is caused by the low funding rates of many agencies. For example, at NSF fraction of research proposals funded has slipped to 20 percent. This means that faculty members are spending a huge fraction of their time writing proposals and also reviewing proposals of their colleagues, with the high probability that these proposals will not be funded. It is my experience, from 37 years in academia, that about one out of three research proposals is truly excellent and easily merits funding. To provide a funding rate consistent with this statistic, one might assume that it would be necessary to increase the annual NSF budget by over 50 percent (to move from a funding rate of 20 percent to about 33 percent). However, a smaller, but still significant, increase might buy much more than is apparent. One reason the NSF and other government agencies receive so many proposals is because the probability of funding is so low. When a proposal is not funded, the faculty member typically reworks the proposal and then resubmits it, or else creates a proposal on a different topic. This proliferation of research proposals is bogging down the system, causing a waste of time and resources, and is part of the reason for low funding rates. In a sense we are running the research system at an inefficient operating point. In my opinion, it would be far more effective to fund the research agencies at a somewhat higher level, driving down the number of research proposals that are written and reviewed, in which case funding rates would rise and researchers would spend far more of their time actually doing research.

The U.S. research enterprise has been and must continue to be a strategic national asset. As we look to the future, the Nation will be well served by major research investments in selected areas supporting economic competitiveness and national security. The European Union has followed this path for years, sometimes taking a "moon-shot" approach. Likewise, the U.S. military has pursued an "offset

strategy," when appropriate. The NNMI program, which is a large targeted investment, may prove to be a good example of a strategic innovation investment to foster U.S. competitiveness in the global economy.

In closing, today's engineering students and faculty share a heartfelt passion to make a difference. Our faculty provide students with a firm grounding in fundamentals, and also with the ability to learn, adapt and create as they move through their careers. We must provide our faculty and students with the resources needed to explore and innovate. The nation will be the beneficiary. Federal programs and policies are critical in this regard.

The CHAIRMAN. Thank you, Dr. Munson.

Dr. Droegemeier, you just finished serving a term as the Vice Chair of the National Science Board, the advisory body for the NSF. Based on your experience in that role, what can the Federal Government do to better manage and prioritize its R&D investment portfolio to improve predictability for research initiatives, facilitate the discovery of new knowledge, and drive lasting economic growth?

Dr. DROEGEMEIER. That's a very good question. How it works now—and I think it works very well—is that it—it's really a team sport. We look at prioritizing research investments by listening to the community, thinking about what big ideas are out there. We look at national needs, as informed by the White House, as informed by Federal agencies, as informed by groups such as the Association of American Universities. So, we put all that together, and we look at available dollars, and we see which priorities really are most appropriate for putting forth.

In fact, NSF just went through an exercise with its leadership team to come up with several major topics for the future—actually, six major research topics and three process topics for the future that we think have very substantial benefits to the Nation, but also are very deep intellectual challenges that might take many, many years to fulfill. So, it's the process, really, of thinking very carefully about what needs to be done, but also providing opportunity for other people to come up with ideas as time goes on so that you don't prescribe, necessarily, the outcome or pick winners, but also you create priority areas, but then you also allow a lot of freedom for people to create on their own and bring forth ideas that could be funded, as we heard just a moment ago.

The CHAIRMAN. The NSF Inspector General and the National Academy of Public Administration have recommended actions to improve NSF's financial oversight of high-dollar, large research facility construction projects. Based on your experience, what improvements to oversight of these projects would help ensure that we are getting the most out of the Federal research dollars that we allocate to NSF, and to ensure, also, the efficient use of taxpayer dollars?

Dr. DROEGEMEIER. Right. Yes, that's a very good question, as well.

NSF and the National Science Board commissioned the National Academy of Public Administration to undertake a study to look at especially the use of cooperative agreements for constructing large research facilities. In this regard, NSF is sort of a unique agency, in the sense that most agencies that build large things do so through contracts. In the case of NSF, these facilities are built for the community, not for the Federal agency, so the cooperative

agreement is the most appropriate mechanism. So, what we looked at in the NAPA study were a variety of issues, such as incurred cost audits, looking at how one applies a management fee to get contractors who will actually operate the facility on behalf of NSF, because NSF does not operate facilities. It also looked at contingency funds and how contingency funds ought to be appropriately managed and supported. Also, the expertise within NSF itself, in terms of people who are certified project managers to oversee these kinds of things, looking at where, within the Foundation, these kinds of projects ought to naturally be homed and located.

The National Science Board undertook a fairly careful look at itself to see what it could really be doing. And we realized that we needed to have greater continuity among activities on the Board. Sometimes these projects last for 40 years, and we have NSF directors come and go, NSB Board chairs come and go, members come and go on 6-year terms. So, these things far outlast the terms of any individuals, and we felt there needed to be greater continuity of understanding about decisions that were made and things like that.

So, those are some of the actions that NSF has already taken, and is taking, including adding new staff to the large facilities office to really kind of beef up and bolster the expertise that is available. I think also, as we learned at the Board meeting last week, being very careful to make sure that the folks who are in the NSF who are running these projects have the requisite experience to manage these projects, not just being good scientists, but also really understanding the nuances of things like earned value management and all the very detailed aspects of executing on a very large project.

That NAPA study turned out to be extraordinarily valuable to us, and I believe the IG and NSF are working very well together to make sure those things are implemented. In fact, the NSF agrees with, basically, all of the recommendations in the NAPA report.

The CHAIRMAN. Dr. Wing, you've had experience in academia at Carnegie Mellon, in government at NSF, and now in the private sector at Microsoft. What roles do you believe that the Federal, private sector, and academic actors are best suited to play in bridging the so-called "valley of death" and in reducing barriers to domestic full-scale production of innovative products?

Dr. WING. Well, first of all, I very much appreciate your question about, essentially, the government/academia/industry ecosystem—research ecosystem. Each agent in this research ecosystem has a very critical role for advancing science and engineering in basic research for the country. Federal funds, obviously, support basic research in universities; the private sector does not typically fund basic research at universities, for sure. And the basic research advances science and engineering; but, more importantly, basic research also produces the talent on which industry very much relies, in then taking the ideas from basic research and going the next step to create new technologies that, in the end, help the economy and benefit society.

So, each of the agents in this research ecosystem feed on each other. It starts, of course, with Federal funding of basic research for universities.

The CHAIRMAN. But, tell me, how does the availability of STEM graduates affect corporate decisions at Microsoft? For example, where to conduct research or to build a business or manufacture goods, things like that.

Dr. WING. Companies like Microsoft, but indeed the entire IT sector, are feeling that there is huge demand for very little supply. Let me give you a statistic.

There are currently 550,000 open positions in computing. And guess how many computer science graduates we have annually, nationally? Fifty thousand. So, there is less than 10 percent supply for the demand. And this demand is going to grow. The demand for computer science graduates, or the demand for people skilled in computing, is just going to grow, because all sectors, not just the IT sector, need a workforce skilled in computing. All sectors see the importance of software in their future, the importance of data analytics in their future. And all of those kinds of skills are what computer scientists learn.

The CHAIRMAN. Thank you, Dr. Wing.

Senator Peters.

Senator PETERS. Thank you, Chairman Thune.

During the roundtables that we held with Senator Gardner and I, we certainly heard an awful lot about the need for basic research and how that is the fundamental aspect of innovation in this country. Dr. Wing, you just talked about that, as well, in that you need basic curiosity-driven research that kind of goes wherever it may go. And it is a unique government function to support that. We heard that, you know, public companies are not going to be able to do that kind of research, particularly because of the demands that they have from their investors and their shareholders.

Could you perhaps—first, Dr. Wing, and then others, as well—expand on why this is a unique Federal role and that we have to step it up considerably if we expect to be competitive, globally?

Dr. Wing.

Dr. WING. Just as you mentioned, for companies, a company's mission is typically to make money for their shareholders. It's not about doing basic research, and it's certainly not about funding academia. So, the Federal Government has a unique role in this research ecosystem, which is to fund the basic research in universities that then leads to new technologies that can then become new innovations that either turn into startups or go into industry.

Companies typically do not fund basic research in the way that the Federal Government can fund basic research. And companies do look to academia for partnerships, where the people and the ideas coming out of federally-funded research emerge. Indeed, that is a benefit from industry/academia partnerships.

But, for the most part—and I must say that Microsoft is uniquely different in this way, in that Microsoft does fund basic research—companies cannot and do not fund basic research in the way that the Federal Government can and should.

And let me draw an analogy here. The Federal Government funds basic research to ensure the success of the country, much

like Microsoft funds basic research to ensure the success of the company.

Senator PETERS. I appreciate that and your comments that it is a unique role. I would go even further, that it is a fundamental role, that all of the other stuff does not happen without the government investment in basic curiosity research.

Any other panelist want to elaborate on——

Dr. WING. I completely agree. Thank you.

Dr. DROEGEMEIER. I would just add that it's difficult to build a business plan off of uncertainty. Private companies don't like uncertainty; they like certainty. Shareholders like uncertainty. The Bureau of Economic Analysis likes certainty in predicting what the next quarter of earnings will be in this country. So, I think the basic research is unpredictable, but that's—its very nature, it's unpredictable. So, it's high-risk. It has an uncertain valuation. But, we do know from—through the lens of history, that, without basic research, things like the iPhone would not have happened, because Apple did not invent anything that was in the iPhone. They innovated the capabilities that were funded by the Federal Government and others, you know, many decades prior to that, and came up with this incredible device, but they did not actually do any of the research. And I think that's a great example of a company doing exactly what Dr. Wing said, of taking the investments that the Federal Government made many years ago without really knowing how they would be used, and then innovating to create jobs and build economic strength and even, you know, capabilities that we couldn't imagine back then.

Senator PETERS. Well, that leads to the point that we should move away from having an emphasis on a special application or a specific application for the research, and have it wide open.

Dr. Munson, I think you've talked about some of these issues in the past. If you want to expand a little bit on the fact that if we have a Federal emphasis on research with a specific application, we are probably hurting the scientific innovation ecosystem.

Dr. MUNSON. I think probably we need a balance. And I am in favor of some direct Federal funds directed toward application areas, like manufacturing, which is very broad. The university work that we do in partnership with industry does tend to be more applied than the work we do with the Federal Government, and tends to be application-specific, in that we might be doing work on a specific component of a driverless car, for example; whereas, with the Federal research, it's going to be more basic, often more mathematical, in the case of engineering, and develop underpinnings for future discoveries. So, I think we cannot lose the fundamental basic nature of Federal research, but I also feel that targeted investments in specific areas is sometimes merited.

Thank you.

Senator BLUNT [presiding]. Mr. Udall.

STATEMENT OF HON. TOM UDALL,
U.S. SENATOR FROM NEW MEXICO

Senator UDALL. Thank you very much, Chairman Blunt. Doesn't that have a nice ring to it?

[Laughter.]

Senator UDALL. I appreciate the hearing topic today and this committee's bipartisan work to update and reauthorize America COMPETES legislation.

New Mexico is home to many scientists, from university researchers to those in our National Labs working to keep our country safe, from astronomers peering into the depths of space, to climate researchers trying to understand the impact of global warming on our forests and grasslands. So, I look forward to working with Chairman Thune and with you, all of the Committee members, as we consider America COMPETES legislation. And I'm eager to find ways to encourage women and underrepresented minorities to pursue the STEM fields and improve tech transfer from federally-funded research.

Mr. Atkinson, as you know, New Mexico is home to Los Alamos and to Sandia National Labs. These are truly crown jewels in our Nation's research-and-development infrastructure. Your organization partnered with the Heritage Foundation and the Center for American Progress on a report called "Turning the Page: Reimagining the National Labs in the 21st Century Innovation Economy." That report recommended changes to how our National Labs are managed. It found that the National Labs are a tremendous source of cutting-edge research and scientific talent. But, it noted that the labs could benefit from new management models that are best suited to nurture innovative ideas. Could you share more about your ideas for how our National Labs could do a better job, in terms of tech transfer and commercialization?

Dr. ATKINSON. Yes, thank you, Senator Udall.

I hundred-percent agree with you, the labs are an enormous asset. And, unfortunately, they're underperforming, in terms of taking that knowledge and getting it out into the private sector. There are a lot of different reasons for that. One of the reasons is, frankly, there's too much top-down control in Washington, at DOE headquarters. To get the lab to have some flexibility to get something out into the marketplace is very onerous at times. Idaho National Labs recently cataloged 110 different requirements for them to meet in order to transfer a—some technology out of that lab—110 different requirements. When you have to go through that, it becomes much more difficult. So, we made a number of recommendations, one being that Congress should remove prescriptive overhead accounting rules and allow labs more flexibility with their funds. Again, a lot of the funds are very stovepiped. If they want to move a little bit of money over here to try something new, to maybe prototype it, see if it's ready to go, see if they can get it out into the local marketplace, very difficult for them to do that.

We also argued for expanding what are called Agreements for Commercializing Technology, or the ACT program, which right now is very limited to certain types of companies. That should be a broader program. We think it's very good program. There's also a process called the PEMP, the P-E-M-P process, which is an evaluation or accounting—accountability process for the labs. But, when you look at what the PEMP measures, the technology impact measure or technology commercialization measure that—how the labs are evaluated accounts for very, very little in their evaluation. And so, a very simple thing would be to have DOE make technology

commercialization a more important factor in how the labs are evaluated. Companies and organizations do what they're evaluated on. And if you don't evaluate them on that, if it doesn't really matter whether they do better or worse, then they're not going to do very much. So, I think there are a lot of different things that we could do with a—to really ramp up their capability.

Senator UDALL. When you talk about the 110 requirements, are those part of the top-down, that they have to do or are these internal ones, even, in the laboratory itself?

Dr. ATKINSON. I'd have to go back and look and see how many are which, but certainly there are many of these requirements that are either in regulation or just in terms of the bureaucratic process that goes on here in Washington headquarters. Some labs also have internal processes that they, themselves, could streamline. But, again, sometimes their ability to streamline those are constrained by Washington.

Senator UDALL. Yes. They now have one person dedicated in the Department of Energy to look at tech transfer, to look at commercialization. Do you think that's a step forward, in terms of that kind of issue?

Dr. ATKINSON. It's better than zero.

Senator UDALL. Yes.

[Laughter.]

Dr. ATKINSON. But, when you think about——

Senator UDALL. That's the way I feel, too.

Dr. ATKINSON.—the amount of money that the labs spend, or we invest in the labs, and yet we have just one person doing that, it really tells you where the priorities are.

Senator UDALL. Yes.

Dr. ATKINSON. And I knew the prior person who did it, who was a wonderful person, and—but, frankly, it was hard for her to do that, because she's just one person looking at the entire lab system.

Senator UDALL. Yes.

Thank you very much. Really appreciate it. And I may submit a couple of questions for the record.

Thank you.

STATEMENT OF HON. ROY BLUNT, U.S. SENATOR FROM MISSOURI

Senator BLUNT. Thank you, Senator.

I have one—we talked about the labs. That was helpful. I'd also like to have a little on-the-record discussion here about the regional innovation programs. These are programs that, with a one-to-one match, try to leverage and build the innovation ecosystem. We were able to put these in the Blunt-Brown manufacturing bill that passed this committee in 2014, and was enacted into law. So, they're extended through 2019.

In Missouri, we have eight of these regional innovation programs. You know, one good example would be BioSTL, in St. Louis, where a coalition of not-for-profits, of community leaders, university leaders have pushed to make this environment work. And they've received a number of grants, and are having great success. But, I'm just wondering, on that regional concept, if any or all of

you have any experience or anything you'd like to mention as to how those are working.

And, Dr. Atkinson, we'll start with you.

Dr. ATKINSON. Thank you, Senator.

I fully agree with you that it's an important concept. At a prior position in my career, I actually headed up innovation and economic development for a Governor. And I can tell you, Governors, by and large, understand this question better, frankly, sometimes than Washington, because they're closer to the ground on it. But, they're often constrained in the resources they have. And I think a program like the Regional Innovation Partnership Program, because it's a targeted program—not a lot of money, but enough money to kind of bring everybody to the table and organize these.

We have a dynamic and very different and diverse system in the—between states. You have the bio-efforts in St. Louis, Rochester has optics. It's hard for the Federal Government to think about that. And it really requires a regional focus. And for the Federal Government to put a little bit of money into this to spur that, I think is a very wise investment.

Senator BLUNT. Anyone else?

Dr. Wing.

Dr. WING. One of the recent programs that the National Science Foundation put out is a data hub program, which recognizes the importance of big data in all science and engineering disciplines; in fact, beyond science and engineering, in the humanities, arts, and social sciences, and so forth. There are four regional data hubs that were created in somewhat of a hub-and-spoke model so that all universities and research institutions in those regions can benefit. I think that all four hubs are doing very well in addressing very important concerns for society.

Dr. DROEGEMEIER. I would just add to that. When you think about these regional hubs, which I think are so important, a lot of times they're focused around major research universities. And that gets us back to the question of, how easy is it for private companies and universities to work together? And I hope, at some point, we might talk about that, because I think there are some significant impediments. Some of these were pointed out in the American Academy's report, that the COMPETES Act could be sensitive to it and really drive some important change that I think would unlock potential that is now kind of bound up in certain laws that are tying our hands.

Senator BLUNT. Thank you all.

STATEMENT OF HON. CORY GARDNER, U.S. SENATOR FROM COLORADO

Senator GARDNER [presiding]. Thank you, Senator Blunt.

And thank you very much for the witnesses' time here today and the work you're doing.

What's that? Oh, I'm sorry.

Thank you very much for the time to be here today. And really appreciate the work that we've been—you've helped us put together on reauthorization of America COMPETES. It's incredible what we have been able to find and learn together on this.

And, at this point, I think I'm next in questioning, but I'll go ahead and give the time to Senator Klobuchar for the next time period.

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

Senator KLOBUCHAR. OK, very good. I thought you were ending it. That's what I was sort of motioning that I wanted to——

[Laughter.]

Senator KLOBUCHAR.—that I wanted to say something. So, it——

Senator GARDNER. I thought you really, really wanted to ask a question, so I said, "Man, I'm going to let you do it."

[Laughter.]

Senator KLOBUCHAR. No, it's not. I'll be very brief.

But, I want to thank Chairman Thune and you, Senator Gardner, as well as everyone that has been involved in the COMPETES Act. It's pretty important in my state, where—we're a state that makes stuff, invents things, and exports to the world. And we've had a lot of hearings about this.

So, my first question is about the STEM workforce. I guess I'll ask this of you, Professor Munson. Do you believe that increasing the number of STEM secondary schools will better prepare students? Senator Hoeven and I have worked on this, and—at the home of the Mayo Clinic and other places that do a lot of technology, like medical device. I care a lot about this. So, how do you think that that will help, if we increase the number of STEM high schools?

Dr. MUNSON. I think it's important to better integrate STEM throughout all our high schools. And so, I think it's great to have a set of high schools that focus on STEM, but it pains me to see any high school, for example, that teaches nothing in the area of computer science. And the engineering deans across the Nation now are working hard on various proposals to have at least introductions to engineering available throughout high schools. So, I think that's important.

What I'm most concerned about there, though, I have to say, is getting more women and more underrepresented minorities into STEM, because we know that, in just a few short decades, if not sooner, the current minority will be the majority in the U.S. And at that point, if we have very few minorities in engineering and technology and science, if we have very few women in engineering, in technology, and science, that we're going to be drawing on all of our technical talent—we're going to be drawing on about 25 percent of the population. And there is no way we're going to be economically competitive——

Senator KLOBUCHAR. Right.

Dr. MUNSON.—if we do that.

Senator KLOBUCHAR. And we've started this diversified tech caucus, with myself and Senator Capito and Senator Scott, that's pretty important. One of the things I've found is that a lot of people—especially women just don't like some of the work environments, in how they're set up. I've been in manufacturing facilities in Minnesota. They can be really freezing cold. And then I ask their General Manager about it. This actually happened. I said, "Well,

maybe people aren't working here because it's so cold." And he says, "No, no, that's not it." And then I put it on Facebook that I visited there, and three people wrote in, "Oh, my brother used to work there, but it's so cold."

[Laughter.]

Senator KLOBUCHAR. And so, I just think that thinking not how things were 20 years ago, but thinking about how you're going to recruit people, millennials, of any color or any gender that want to have a different working environment is part of this, as well as having mentors and everything we know. So.

Dr. MUNSON. My impression is, the larger companies are doing a really good job at creating a much improved environment, but part of the hard thing is, at the university level, getting the message out to students that, in my case, engineering is not a solitary profession. You're not——

Senator KLOBUCHAR. Right.

Dr. MUNSON.—hidden away in a dark lab by yourself, you're not chained to your computer workstation.

Senator KLOBUCHAR. Or your cubicle. And it's a——

Dr. MUNSON. No, it's——

Senator KLOBUCHAR.—more open place——

Dr. MUNSON.—it's a very social profession these days.

Senator KLOBUCHAR. OK. All right. They're—you're on record saying that, so that's good.

[Laughter.]

Senator KLOBUCHAR. No, I believe you, Doctor. I've seen it myself in companies that encourage that kind of collaboration.

Dr. Atkinson, I know you've done a lot of work—I've done some work with you on this—is trying to get products that a university researches so it just doesn't get dust on a shelf and so that, instead, it's sort of translated into products. Can you talk about that and what new steps we could take to try to encourage that?

Dr. ATKINSON. Yes. Well, thank you, Senator.

I just want to also compliment you on your bill for the science high schools. I think it's one of the single easiest and best things we could do. If you looked at the National Science Bowl winner last—I think it was last week—was Montgomery Blair, right here in Montgomery County—won the entire country's contest. And it's a science-focused high school. And I think we—if we're going to get excellence—and, by the way, if you look at a lot of those high schools, they do a very, very good job of getting girls involved. And so, I think expanding that and having more experimentation around the country is really critical.

On the whole issue of tech transfer, part of our challenge there is—again, we've got a great diversity between universities and then within labs. The challenge we have, though, is, frankly, a lot of universities and labs don't have strong incentives. They're happy with the way things are. They just want to keep getting grants from the Federal Government. And they don't have strong incentives to commercialize. And, second, even the ones that want to do more don't necessarily have the resources. And that's why I think things like the I-Corps program, things like the initiative in the Startup Act that would take a little bit of that—a little bit of SBIR money, if you will, and move it into commercialization, the Regional Innova-

tion Program that Senator Blunt talked about—these are all really important areas to get the resources for people who want to do commercialization better.

Senator KLOBUCHAR. OK. Very good.

Well, thank you.

And thank you so much, Senator Gardner.

Senator GARDNER. Thank you.

Dr. Wing, did you wish to——

Dr. WING. I——

Senator GARDNER.—reply, as well?

Dr. WING. I wanted to follow up on what universities can do to expedite or encourage faculty to take ideas and create startups and do tech transfer, to address this valley of death that was introduced earlier. And that is, universities can be a little more creative in their technology transfer policies. I believe that my former provost, Mark Kamlet, from Carnegie Mellon, spoke to Congress in 2010 about the CMU tech transfer policy. What happens at a university is that faculty have an idea, they might want to do a startup, and then there's this upfront negotiation with the tech transfer office. There's all this time spent on negotiation because the university is worried about, "Oh, who is this money going to? There's going to be all this money, and the university should own some of that money." But realistically how many startups really succeed? So, there's all this upfront negotiation, and people are hired into these positions in the technology transfer office, and this creates more overhead and so, what Mark Kamlet did was he instituted this principle of "5 percent, and go in peace." Now, there's a short one-page form you fill out—very simple and not a lot of negotiation, which reduces the staff and which reduces the upfront overhead and negotiation. The faculty are happy and the university will get something if the startup succeeds. That's an example of being creative. So, I think universities can look to themselves and say, "If we want to promote more tech transfers, we want to promote an entrepreneurial culture on campus"——

Senator KLOBUCHAR. And is 5 percent kind——

Dr. WING.—"we can do that."

Senator KLOBUCHAR.—of a normal amount?

Dr. WING. Of—5 percent of equity——

Senator KLOBUCHAR. I know.

Dr. WING. Yes. That——

Senator KLOBUCHAR. Is that——

Dr. WING. Yes.

Senator KLOBUCHAR. That's—OK.

All right. Thank you.

Senator GARDNER. Thank you very much, Senator Klobuchar.

And I understand your concern about weather, but if there are any Vitamin D-deprived scientists or engineers, you're always welcome to Colorado. It's——

[Laughter.]

Senator GARDNER.—sunnier there than any other state in the country. I'm just going to say that right now.

[Laughter.]

Senator GARDNER. But, thank you again, all, for being here and, to Senator Peters, for the work that we've been able to do together.

The roundtables that we've held here in Washington, I think, have been very successful, very eye-opening. And, of course, we've learned a tremendous amount about how to build on a successful program. And if you look at the innovations that we have brought to this country through the work the Federal Government has participated in, from the barcode to touchglass on an iPhone, Federal research has contributed to many of the most well-known and important projects and important technologies this country is now living with or, in many ways, couldn't live without. And so, the funding issues are critically important. We have to recognize the U.S.'s leadership role in funding, and doing it better than any other nation in the world. But, we can also always do a better job, and that's what this effort is about, how we make sure that we can continue competing as a leader, not a follower, in this globe, where China, India, and other nations, Japan, are increasing their commitments to research, development, basic science. And so, how do we make sure that the U.S. maintains that leadership role? And so, our effort, of course, builds on the 2007 RAGS report that we've talked about throughout this entire roundtable process from last year to this report, "The Rise Above the Gathering Storm," America COMPETES, and the authorization.

And so, building on that, that report, building on the innovation edge that we have today, but it's not guaranteed, it's important that we have the advice from the academic sector, from the private sector, from others who are integral to making this Nation maintain its position—helping this Nation maintain its position on top. And industry, of course, and the partnership that they provide.

So, over the past year, thanks to those of you who have participated in the roundtables, we've held a number of them, both in Michigan—I think you did some in Michigan—we did it in Colorado, where we have over 20 Federal labs that will partake in the work that we do today. Of course, in Washington, D.C. So, thank you.

A lot of questions that I have—I wanted to get to my questions now and just start with one of the comments that was made during, I think, Dr. Droegemeier, your opening statement. I think you said something to the effect of, "There are no sure bets, and winners are found where they're least expected." And then, follow that up with, I think, something that Dr. Munson had stated, which was, basically, something to the effect of, "If there's no market for it—it may be the best technology, but no market"—something to the effect of, "No market for the best technology doesn't really get it anywhere," if I could paraphrase. And then, Dr. Droegemeier, you talked about reducing the administrative's burden.

So, how do we make sure that we're taking this 42-percent administrative burden, we're reducing it so that more money can be spent on the science, on the research, so that more time by the researchers can be spent on the science, the development, the research, while also recognizing that we have accountability and transparency needs and commitments to the taxpayers of this country, balancing that with, "The winners are found where they're least expected"? That's a difficult task. How do we best achieve that balance?

Dr. DROEGEMEIER. Well, I think we're on a right track, in terms of looking at all these various compliance policies and saying, "Are they really working? Are they having the intended purpose? Are they preventing waste, fraud, and abuse? Are they allowing the safe research in human subjects?" For example, in some cases, universities are bound by policies for, say, the application and the storing of chemicals that are relevant to industry, and yet we don't have the—nearly the amounts of those chemicals on our campuses. So, there's an example of having to comply with a policy that's completely incongruent with the nature of a university. Certain reporting requirements that—of providing information to agencies, we're all about doing that, but then the question is—if every agency is asking for the same thing in a different form, there's duplication. So, what we want to do is understand the—if there is duplication, try to harmonize and streamline those things and avoid situations where we're doing a lot of work that doesn't need to be done. It's, maybe, already done in some particular way.

And so, I think there has been a thoughtful analysis. The National Academy is about ready to come out with the second part of its study. And so, I think that analysis has been done. Now I think we have to have the will to actually implement that. And you'll notice that some of those recommendations are for the universities themselves. Sometimes we put additional regulations on ourselves, because we are very concerned about being sued, for example, if there's a particular situation that happens. So, we say, "Well, let's go ahead and add on this additional regulation." And, of course, the faculty don't distinguish, "Is it a Federal regulation? Is it a university? Is it a State regulation?" They just see this as a big burden. So, trying to tease out, I think, the various natures of those compliance mandates and whether or not they're actually having the intended effect.

And then, as we add new compliance mandates, like for lab safety, are we looking at the cost and making sure that these things are being implemented in a way that's consistent with the research that's done in universities, versus, say, that at a Federal lab or in a private company?

Dr. WING. May I make a comment on that?

Senator GARDNER. Yes, please.

Dr. WING. I want to explain a subtle implication of when—and this relates to the 42 percent of research time that goes to administrative overhead—a subtle implication of when Federal funds for basic research are not sustained. Because what happens is that a faculty member will not know whether he or she will be able to get funding for a graduate student 3 years hence. A faculty member actually might hesitate in even taking on a new graduate student because he or she is not sure of how much funding he or she can expect. So, what happens is that, first of all, being entrepreneurial, a faculty—a typical faculty member will then propose to multiple agencies in order to support, say, one student or a set of students. And then, for each agency, you have these administrative rules to follow. First there's a pre-award process with all the rules. Then you get the award. Then there's a post-award process, with all the rules. These rules are for compliance and accountability and transparency for each of the little pots of money that the faculty was

able to get to support one student or a set of students. And that's just for maybe 2 or 3 years looking forward. So, when the funding is tight and it's not predictable—and that's what I mean by not "sustained"—then the faculty member has to spend a lot of time managing this large portfolio of lots of pots of money. When time goes to administrating grants, less time goes to research, meaning inefficient use of research dollars. Here then is the subtle implication: less time for research means less advancement of science.

Senator GARDNER. Thank you, Dr. Wing.

Dr. Atkinson, you mentioned, in your opening comments, the ability to take—about commercialization—that the ability to take U.S. knowledge and commercialize it for another country's gain is significant. We see the research, the development, the science here, and then the commercialization there. Could you give, perhaps, an example of that, and then perhaps a policy response to that? What are the key things that we should be doing?

Dr. ATKINSON. So, there are clearly examples in a wide variety of industries. So, for example, some of the technologies that Taiwan has developed, in terms of semiconductors, they've used the knowledge we've developed here. But, I think we see that, and we're going to continue to see that. And at one level, science is a global enterprise, and they develop science, and we benefit from it. So, I'm not saying science is a zero-sum game, by any stretch of the imagination. But, at the same time, it is a global public good, if you will, so sort of out there for everybody to capture, and we don't do a good enough job to do that.

So, there are, I think, a lot of things we could do. For example, one of the things would be to expand the Engineering Research Center Program and what's called the IUCRC Program—Industry/University Cooperative Research Center Program at NSF. These were developed back in the Reagan administration, when we faced the Japanese challenge—the Japanese and the German challenge. There was an understanding back then that they were funding cooperative university/industry partnership programs, and we weren't. So, we developed these programs. Very, very successful. But, again, very small amount of money. So, again, you could expand those programs in a budget-neutral way, just tell NSF they have to double the size of those programs. And the advantage of that is, there's a direct linkage. So, for example, the UC Berkeley, they have a microelectronics—MEMS, for microelectronics——

Dr. DROEGEMEIER. Sensors.

Dr. ATKINSON.—yes, sensors—microelectronic—microsensors——

Dr. MUNSON. Micro Electro Mechanical Sensors.

Dr. ATKINSON. Thank you. Micro Electronic Mechanical Sensors, MEMS. And it has commercialized more technology than many, many other places. I mean, it's a little center, but, because they're so tightly linked with Silicon Valley and industry, they take these MEMS tech discoveries coming out of Berkeley, and they get them into the marketplace, because they have an industry/university focus right there. So, I think something like that would be very helpful.

Senator GARDNER. Thank you, Dr. Atkinson.

Senator Moran.

STATEMENT OF HON. JERRY MORAN,
U.S. SENATOR FROM KANSAS

Senator MORAN. Mr. Chairman, thank you very much.

Panel, thank you very much for joining us.

I want to—I have two questions. One is narrow, and one is broad. And I'll start with the narrow one, and I want to direct it at Dr. Atkinson.

Doctor, you have been valuable to us in many of our efforts in regard to trying to increase upward mobility in the economy for individuals, but particularly in regard to legislation introduced now a number of years ago, Startup—now Startup 3.0. One of the components of that legislation is trying to enhance the opportunities to commercialize federally-funded research to get it further into the economy and to help startup entrepreneurs have access to the value of research that they have helped fund. And I would welcome your thoughts about that and its proper place of—in the COMPETES Act as an opportunity for us to advance this cause.

Dr. ATKINSON. Well, thank you, Senator. Thank you.

You know, I think it's interesting when you look at that—first of all, fully support that idea and that proposal, and Startup Act, in general, taking a very, very small amount of money. I think it's 0.15 percent, as I recall, out of the entire enterprise, and saying, you know, if we take a little bit of money and focus it on getting this knowledge commercialized in the U.S., to me that's a very, very wise investment. And not just because it would get more commercialization, but it would end up creating a more positive ecosystem. We'd have a bigger economy, so we could fund more science. We'd have industry more focused on this thing, so they would be funding more university research. So, I think the folks who are looking at that, maybe with some trepidation, are saying, "Well, we have a fixed pie, and we don't want to lose our little slice," are looking at it in a too narrow and not the right way, because I think a program like that would end up with commercializing a lot more innovation and fundamentally creating more science.

Senator MORAN. Thank you. We're working with the Senators on this committee to see if we can't include that language or similar language in COMPETES.

On the broad question, to any of you who would like to respond, I think the question is, is all Federal research of equal value or priority? And I know the answer to that can't be yes, but also, I think, probably, politically, it can't be no. But, here's what I'm thinking. I've been involved, as a member of the Appropriations Committee, in regard to significant increases in NIH funding. I now chair the Agricultural Appropriations Subcommittee, where there's a concerted effort to see if we can't increase the number of dollars available for agriculture research. We're talking about other research today in this setting. But, as I, as a Member of Congress, try to prioritize, where do we put the resources within the wide array of federally-funded research, how should I look at where those priorities ought to be? So, the question, again, is, is there a way to distinguish that certain kinds of research, federally supported, has a better bang for the buck, greater value to the country, its economy, and its people?

Dr. ATKINSON. I could start. So I know that the consensus in the academic community is that it's all equal and they shouldn't allow any prioritization. The prioritization should come from principal investigators. And I don't really believe that, nor do I believe the opposite, that the Federal Government should be micromanaging and picking everything. You need a healthy mix of that. But, I do think that there is one good criteria that we could use, and that's from a report we released on Monday about how—why we need a national productivity strategy. U.S. productivity over the last 7 years has been the lowest it has been since World War II. I think there's a set of technologies, including in agriculture, including in biotechnology, including in robotics and artificial intelligence and others. We know these technologies are going to be critical to boosting U.S. productivity, and I don't see any reason why we couldn't say, "We're going to take a little bit more focus into these areas." Again, it's not to say that you abolish meteorology or anything like that. I'm not saying that, by any stretch of the imagination.

[Laughter.]

Dr. ATKINSON. But, I am saying, though, that we do know that there are some areas of research that are going to have a bigger economic impact. And I think it is worth expanding those, in particular.

Senator MORAN. Thank you.

I think it was recognized several years ago that we, as a Nation, don't really have a science-of-science policy. We make science policy sort of as we go. And so, NSF has a problem—a program called SciSIP, the Science of Science Innovation Policy, where we're actually studying this to really find out what—really, the answer to your question. I think one of the answers, though, right now, is better coordination. The National Science Technology Council, which is a Federal agency, a committee that, basically, is across all of government, across all agencies—for example, you look at USDA and things like food safety. There's a lot of basic research and biology at—that NSF funds that's super-relevant to food safety in USDA. So, then the question is, "Well, do you need to have it funded four or five different places and are we properly coordinating our investment?" So, I think—I would say, let's take what we have and make sure that we're coordinating it most effectively, and having crosstalk across the agencies of the bio director at NSF talking with USDA, which I know they are, to make sure that we're really thinking holistically about these problems, as well as the social/behavioral dimension of how people are responding to genetically modified foods and things like that. I think that broad, sort of, ecosystem is really the thing that we have to get our hands around. It's very complicated. It's difficult to do.

Senator MORAN. Doctor, thank you. That's useful to me. I mean, our subcommittee has jurisdiction over both USDA and the Food and Drug Administration. The question very well may be one that we ought to look at in that regard.

And just finally, Dr. Wing, I met with the CEO of Microsoft recently. I very much appreciate the efforts at—that Microsoft is making to train, educate—to encourage the training and education of folks in science and engineering, and computer science, in par-

ticular. And we want to be an ally in that regard. So, thank you very much.

Dr. WING. Thank you very much.

Senator MORAN. Thank you, Chairman.

Senator GARDNER. Thank you, Senator Moran.

Senator Markey.

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

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

We are home to the best research universities in the world. And people from around the world flock to the United States so that they can do their research in the United States. I am proud to come from Massachusetts, where we have some of the finest research institutions in the world. That's why right now we're the home to the largest clean-tech incubator, Greentown Labs, in the Nation. And it's why General Electric is moving to Massachusetts, because we are now the Internet of Things up in Boston as it relates to biotech, as it relates to clean tech, as it relates to telecom tech, and manufacturing. All of this as a result of kind of basic research that was begun and initially given the funding to BB&N, a small company up in Boston, because IBM and AT&T did not want the contract to build a packet switch network. That basic research ultimately then leads to General Electric coming back, and other companies who didn't want the contract, saying, "Maybe we should go to Boston now, where that happens." Sometimes what it is that we are doing doesn't necessarily relate directly today to the economic growth that we're looking for, but, nonetheless, the research has to be done without knowing the specifics.

So, that's why we have to continue to increase funding for STEM research, why ensuring that aquariums, museums, other research-related institutions are also given the funding which they need, because people learn through those means.

Our funding decisions for basic science research should be guided by the possibilities promised by science and technology, and not by politics. A recent version of COMPETES released by the Republicans over in the House has singled out certain sciences as winners, and other sciences as losers, authorizing funding increases for the former and decreases for the loser sciences. Now, this is a narrow view, from my perspective, of how advances in one area of science drives breakthroughs in seemingly unrelated fields. Science operates in a complex research ecosystem, and legislation should support the full range of science inquiry.

Dr. Munson, do you agree that research should be guided by scientific experts and not micromanaged by policymakers?

Dr. MUNSON. I agree 100 percent.

Senator MARKEY. OK.

Dr. Wing, how do you feel about that?

Dr. WING. I agree 100 percent, as well.

Senator MARKEY. So, I would like to enter into the record two letters that detail how Federal investment in geoscience research—and education, in particular—contribute to our Nation's economic competitiveness.

The first letter, signed by 100 universities, research institutions, and scientific professional societies, provides concrete examples of how geoscience is essential to tackling national challenges ranging from workforce development in the energy sector to mitigating the impact of hurricanes through improved forecasting and response.

The second letter, signed by 19 geoscience organizations, including the American Association of Petroleum Geologists, the Society for Mining, Metallurgy, and Exploration, and the Geological Society of America, detail how geoscience plays a critical role in tackling national challenges in water, in mineral resources, energy independence, environmental issues, Earth's climate and ocean systems, and mitigation of natural hazards.

And I would ask——

Senator GARDNER. Without objection.

Senator MARKEY.—unanimous consent that those letters be included in the record. And I thank you for that.

Dr. Wing, in your testimony, you highlighted the importance of investment in basic discovery science. U.S. technological and scientific leadership relies on Federal funding of basic science research and STEM education at agencies as the National Science Foundation. And the LIGO scientific collaboration and international project of over 900 scientists led by MIT and Caltech is a recent testament to the payoff of long-term public investment in basic science research. One hundred years ago, Albert Einstein predicted that violent events in the early universe shocked the cosmos, sending gravity waves rippling through the fabric of spacetime. Creating much of their own technology in the process, scientists were able to detect the vibrations from gravity waves that Einstein had predicted. For centuries, humanity has used telescopes to peer into the vast expanses of the cosmos. Now, because of the pioneering work by LIGO and decades of support by the NSF, we can, for the first time, train our ears on those dark reaches, as well.

Can you tell us about some spinoff technologies or other direct benefits that have come from LIGO research?

Dr. DROEGEMEIER. Sure. Thank you, Senator.

That was so eloquent, I want to get a copy of it. Beautifully said. Wow, LIGO is so exciting.

There are a lot of advances now that are being made as we ramp up the sensitivity of LIGO to new types of mirror coatings which could be valuable in all sorts of medical optical devices and so on, to very sensitive electronics for measuring things that are, you know, smaller than the width of a proton. So, all of these kinds of things, when you think about shrinking, you know, device sizes and packaging of computers and so on, I think some of these things—we can predict that LIGO is producing things, just like the space program did, that will really change our world, and other things that we can just have a hint at that, yes, we could see this, and sort of project it forward, that that someday will result in, maybe, a device, where you have a battery that lasts for 100 hours that's the size of a penny or something like that. So, LIGO truly is transformative, for all the reasons you mentioned. I think we're just beginning to get a glimpse of the spinoffs that are possible from it.

Senator MARKEY. So, it could lead to more uniform optical coatings and proving materials used to build the structural components in aircraft, for example. Is that correct?

Dr. DROEGEMEIER. And isolating vibrations. You know, this thing—we have to isolate it from vibrations of the Earth, earthquakes and just natural—cars driving by. Think about other devices that have to be similarly sensitive for microsurgeries and things like that, could be very valuable.

Senator MARKEY. Yes. To some extent, this could have been viewed as "loser science" for years and years and years and years. But, now maybe not so much. Now you can see that there could be practical applications. That's kind of the tension that we have here. Picking kind of already existing winners of today as deserving of even more funding today, but shortchanging the future, shortchanging the scientific research that would give us perhaps even bigger payoffs in the future, although perhaps not during the tenure of any particular Congressman.

So, that's kind of the dynamic tension that does exist. And, honestly, when IBM and AT&T turned down the packet switch network contract, that was a perfect example of how a large corporation in the short frame isn't necessarily the best judge of what, in the long term, is going to give us the big payoff. The very fact that we're now able to talk about these telecommunications technologies in this new dynamic is only possible because of an investment in a "loser science project."

Dr. WING. Well, I wouldn't——

Senator MARKEY. From the perspective of the major corporations of their time.

Dr. Wing.

Dr. WING. I was going to say, I wouldn't call it a "loser," but I would remind everyone that by definition, long-term basic research means taking a long-term view of the research.

Senator MARKEY. No, I don't mean——

Dr. WING. And it means——

Senator MARKEY. I mean that in——

Dr. WING.—it means being very patient.

Senator MARKEY. Dr. Wing, I'm putting it in quotes, OK? I'm talking about winning and losing in the context of how the short-term interest of some corporations or some interests aren't necessarily the primary beneficiaries.

Dr. Munson.

Dr. MUNSON. You know, let me just add that a lot of times you just don't know where basic research is going to take you. And I'll just cite one example from my university. We had researchers, many years ago, working on the highest-power lasers in the world, and doing fundamentally new physics. And some of that gets pretty esoteric, and you kind of wonder, "Well, but what's this going to be," quote, "useful for?" Well, those very lasers are the lasers nowadays used in LASIK eye surgery, because they make very, very precise cuts in the eye. And that wouldn't have been predicted early on in that research.

Senator MARKEY. Yes. So, "congressional expert" is an oxymoron. It's like "jumbo shrimp" or——

[Laughter.]

Senator MARKEY.—"Salt Lake City nightlife."

[Laughter.]

Senator MARKEY. I mean, we're really not scientific experts. So, for us to be picking which of the technologies are going to give us the big payoff, while most of us majored in history or political science or English in college, is maybe a little presumptuous. That would be my argument. I would leave it to the scientific community to make the decisions. We provide the funding, but we don't necessarily have to then, put our thumb on one or the other. That would be my modest proposal.

I thank you, Mr. Chairman.

Senator GARDNER. Thank you, Senator Markey.

And for those of you who thought you were off the hook, we're going to go another round, here. So, sorry bout that. We do have a few more questions, Senator Peters and I do. And, Senator Markey, you're welcome to——

Senator MARKEY. Thank you.

Senator GARDNER.—welcome to join, as well.

Dr. Droegemeier, again, you mentioned in your testimony the importance of talking about the boundaries between different disciplines. All of you have mentioned that in your testimony. You talk about the interface, for example, between NIH and NSF, biological and mathematical, on NIH, NSF, on diseases such as NSF—excuse me—diseases such as Zika or Ebola. Both incredibly important threats that we're facing today that we find solutions to. And so, one of the concerns that we've heard throughout the process of the roundtables is, How do we know and how do we create a system where we understand what different agencies of government are working on so that we can partnership together? Because there may be an issue where they frequently don't know what other part of the government is working on, the research that's taking place. So, how do we best get agencies to talk to one another in advance of some of these efforts, or during some of these research projects?

Dr. DROEGEMEIER. That's a great question. I think the National Science Technology Council, as I mentioned earlier, is one mechanism. I think another mechanism is agencies that are developing their budgets and going through passback in Congress and so on with OMB, there's always an opportunity, I think, to interact. And agency heads, I think, do meet. I know that the head of NASA, Charlie Bolden, and Kathy Sullivan, head of NOAA, and the Director of NSF, Francis Cordova, Director of NIH, Francis Collins—I think they all kind of work together. And then, of course, all the folks within their agencies talk to one another. But, I think that could also be improved, where we are thinking, you know, more across government about how you do these boundary problems, to make sure that the research investments that we are making are really not being duplicated.

Now, I want to hasten to add, though, I—that doesn't mean that just only one person ever does the study, and nobody else. I think there's—the competition in the scientific community is important, because, as we know, you know, science is all about continuous debate, and ideas get refashioned. Something that was thought to be understood, 5 years later, "Oh, we didn't really understand it as

well as we thought." So, I think we have to make sure that we don't conflate duplication with competition,.

But, I think this kind of interaction is very, very important. Advisory committees that various agencies have, I think, interacting with one another, and crossing boundaries. I mean, why not think about having various advisory committees from NSF and DOD, the Defense Science Board, maybe meeting with the National Science Board at some point? To my knowledge, that sort of thing hasn't happened. I think cross-agency interaction is terribly important, especially in these times.

Dr. WING. May I just mention that, in computer science, the networking and information technology R&D is all coordinated. Probably at this point, about 20 different agencies come together and talk about their R&D investments in information technology. So, at least in that particular discipline, there is a lot of very good coordination across Federal agencies.

Senator GARDNER. Thank you, Dr. Wing.

And I want to follow up, too, on the commercialization questions that you've talked a lot about. From the private sector, what is different, and what lessons can we learn from the private-sector research, development, and commercialization that we could apply to the Federal Government that they're either lacking a particular utility that they don't have that the private sector is able to utilize? What could we do to help their commercialization effort, from your experience in the private sector?

Dr. WING. Right. From my experience right now in the private sector, given that I run the basic research labs, we have a similar eagerness to get our ideas into the products and services of the company. And so, we work very hard internally to promote and encourage our own researchers to work very directly in partnership with product groups. Of course, in academia, you have less of an opportunity to do that, and, within a company, you have a very good opportunity, and it's, of course, encouraged.

We also very recently have encouraged our researchers to be entrepreneurial and—in the spirit of the startup culture—to think about going end-to-end, for instance, talking to customers directly. This is something faculty in universities can do very easily. They are free to talk to anyone, and they're free to take ideas, create a startup, go outside, maybe take a leave of absence from the university, and try to commercialize an idea.

And also, big companies can fund research at universities, as a way to work in closer collaboration, that is, to have closer partnerships between universities and industry. Kelvin was alluding to certain rules and regulations that might get in the way of making that collaboration seamless. And so, that's something that Congress can actually address.

Senator GARDNER. Very good.

Dr. Atkinson, you mentioned the IUCs, I think, as part of this. That's the part of the communication, right, with the private sector you're trying to further? Very good.

Dr. ATKINSON. Yes, absolutely. You know, I think one of the challenges in this whole set of issues is really thinking about the role of the university. And I think we have this view that universities—that their self-interest automatically aligns with the national self-

interest. And I think it does, in some cases, and it doesn't, in others. And that's one of the things the IUCRC program is trying to do. It's trying to align their interests with national interests.

We see that, for example, in STEM education, where, frankly, universities are not enrolling and graduating enough STEM students, not because they can't, but because they don't prioritize that. We see that particularly in computer science. And, from a university's perspective, it's perfectly rational. They're, frankly, indifferent to whether they train French literature majors or whether they train computer science majors. I agree that that's perfectly rational from their perspective. It's not rational from governmental or national perspective. We do know that there are certain disciplines, like computer science, like electrical and mechanical engineering, like science overall, that are, frankly, more important to the country. And I think the same thing—we do know that, frankly, in terms of areas of research and technology.

And the fact that we don't pick winners—we do pick winners. If you look at the President's last budget for the NSF, it didn't have the same increase for all of the different agencies within NSF. Some got a little more, some got a little less.

So, I think the notion that somehow Washington can't collectively work together to help identify what the national interest is with regard to science, and then encourage that—I think that's a mistake, frankly. I think that that is the job of Washington, that is the job of Congress and the administration, to begin to better align those issues. So, I—and there, to me, the IUCRC program is a perfect example of doing that.

Thank you.

Senator GARDNER. Dr. Munson?

Do you mind—OK.

Dr. Munson.

Dr. MUNSON. I do want to disagree with my fellow panelist just a little bit. Engineering enrollments across the Nation have swelled in recent years. In a number of universities, they've doubled. Computer science enrollments at my university have tripled in about the last 6 or 7 years. And so, we're sort of in the mode of taking as many of these students as we can. However, the problem we face is one of facilities. You can't teach an English class and an electrical engineering lab in the same facility. And those faculty need very different facilities for their scholarly activities. And so, at my university, we are raising private philanthropy as rapidly as we can to create more facilities for engineering. But, for us, that's the bottleneck. We don't have more space at the moment. We've grown as much as we can.

Senator GARDNER. Thanks, Dr. Munson.

Senator Peters.

Senator PETERS. Thank you, Senator Gardner. And again, thank you for the work that we're doing on this. I appreciate your leadership on this and certainly have enjoyed the questions—the last couple of questions, in particular, and talking about agencies working together.

Just a story from—one of my journeys out. I was with TARDEC, which is the Department of Defense, working on fuel economy within vehicles, which is an important issue for combat vehicles.

You put men and women and risk for fuel to deliver that, so you want high fuel economy. That's in Warren, Michigan. Not too far away, in Ann Arbor, Michigan, is the EPA lab that's also working on fuel economy for a variety of environmental reasons. And they don't talk to each other, which I always thought was a little crazy, given the fact that they are in close proximity. So, we need to do a much better job of, certainly, recognition of competition, but also there needs to be some sort of collaboration there to work together and to move forward.

I also appreciated the comments about science—whether or not it's all equal, if we have the winners and losers, in parenthesis, that you never really know where it may come. I want to use another University of Michigan example, where they were doing research on electrical fields on Mars. And you may say that's somewhat practical for NASA, for missions to Mars, but what does that mean on Earth? But, now there's a company that has been started who used that knowledge to help protect the electrical grid on Earth. Even when you're studying Mars, that has applications to what we do on Earth, which is why we have to continue to fund this, I believe across the board.

And I want to turn a little bit to the process, because it's come up through this testimony that we've heard today, is the creative process of innovation. You don't know where it's going to lead. You need creative problem-solvers as related to the STEM education. Dr. Wing, I know with the work that you've done there and other companies have done to promote scientific competition, for example, with kids. I had an opportunity to be at the Intel award ceremony for the high school winners for, really, some of the best scientific projects in the country. And I was struck by the fact that, as they were going across the stage and explaining their projects, which were amazing, most of those students also were involved in the arts in some way. They played the cello, they were in theater, they had this art education, as well, which enhances the creative process. So, to me, that's an integral part of this. You need to be more than just a great mathematician or an engineer or some sort of scientific discipline. You also need some creative-thinking abilities.

How would you—this goes to all the panel—any advice you would have to us as to how we—one, how important is STEM? And, two, how would we incorporate that in our COMPETES Act? Do you have ideas of things that you think the Federal Government should be doing?

Dr. DROEGEMEIER. Well, the National Science Board, about a year ago, put out a report on the STEM workforce, and it really tried to make clear that, when we talk about a STEM workforce, we're really talking about a multiplicity of sub-workforces. So, when we say, "Well, there are IT jobs, and there's STEM IT and there are computer scientists," that's a very simplified way to look at it. It's a much more nuanced sort of thing.

And we also made the point that STEM careers are very important, but we also have to really embrace the value of the humanities, the arts, and the fine arts, in this whole process, because a lot of the folks that are working in jobs that are not maybe even classified as a STEM job, they actually use a lot of STEM skills.

So, my worry would be, if we went all the way toward having STEM high schools, then where do the arts go? Because that is a very important part of creative, you know, thinking, as you say, about how we actually educate students, how we go about solving a problem. And the folks in the artistic world think of it very differently than we do.

And so, in and of themselves, those disciplines are valuable. They're also valuable in the sense of—for example, folks that do history. They look at historical plays, art history. We've learned a lot about climate change and the environment and human disease and how it evolved with time by studying art, by studying plays that were, you know, developed three-or four-hundred years ago, and also by studying ancient cultures and how they reacted to disease, and we then conflate that with tree-ring analyses and carbon analyses, and we understand climate change. So, it really is—it's really an all-hands-on-deck kind of a thing.

So, I think, when we think of STEM, and you hear all these acronyms—STEAM and so on—to me, it's more—we need to think that STEM capabilities are valuable in any discipline, but we also cannot lose the value of the arts, the fine arts, and humanities, not only for the value they play in the sciences, but for the value they hold with us as human beings.

Dr. WING. I completely agree that it's absolutely important to educate the future workforce, not just in STEM, but also in arts and humanities.

You asked for specific advice or actions you could take. One of the stumbling blocks we face now, especially in computer science, but, I think, in all STEM disciplines, is not having enough teachers who are trained to teach the discipline. We certainly see, at the high school level, there are not enough teachers at the high school who can actually teach computer science. So, we need to get through that hurdle. That's something we can do immediately. And, in fact, once we overcome this hurdle, I am optimistic we'll be home free: all else to achieve my vision of "computing for all" will follow. So, teacher training is important and one thing we can address now.

Senator PETERS. Dr. Munson?

Dr. MUNSON. Yes. We've done a lot of work at the intersection of engineering and science and the arts at the University of Michigan. The engineering campus, so to speak, at the University of Michigan is about a mile from the main campus, and our only co-located units are all the different units in the performing and making arts. And so, we're together with music, theater, and dance, art and design, and architecture. We have an organization that the four north campus deans started called "Arts Engine" that undertakes a lot of programming and workshops and what have you. We have a section of a dormitory, where engineering and arts-related students live together, do projects together. We teach a number of different courses, including courses on creativity that are co-taught by a faculty member in music, one in dance, one in art and design, one in architecture, one in engineering. We also have founded a nationwide organization called the Alliance for the Arts in Research Universities, A2RU. We have more than 30 partners in that still

fairly new organization. Partners include MIT and Stanford, so a lot of name-brand universities think this is important.

In my own case, 70 percent of my incoming engineering students are musicians, and we tell them, "Do not leave your instrument at home. Do not quit singing." A vastly disproportionate fraction of the marching band, the men's glee club, and what have you, are engineering students. I have many engineering students double-majoring in engineering and music, or engineering and art and design. We are including students from the arts in our student project teams in engineering. And I think all this integration is just turning out to be really great.

Senator PETERS. And I guess I just want to expand a little bit on the talk of STEM education. Dr. Wing talked about teachers that are prepared to educate. Dr. Atkinson also addressed this issue. All of our panelists have. But, one statistic that I saw that is—then I want to raise a question as to why this is the case—there's a study that showed that 40 percent of students who begin college as STEM majors actually complete the degree. So, that's a pretty high attrition rate happening, or out of universities. What's happening there? And what policy advice do you have for us? Any panelist.

Dr. Atkinson?

Dr. ATKINSON. So, I think this really gets to the challenge, here, which is that fundamentally, from a university's perspective, they're indifferent to whether student transfers out of STEM to go into French literature. It's the same to them. There's a number of good studies, that we have reviewed in a prior report, that shows that switch-out rates are quite high. And, in most of those studies, they show that the people who switch out are not any worse off, and they're not any worse students. So, it's not as if they're—it's not as if these programs are essentially weeding out the weak and the incompetent and just keeping the cream. They're actually weeding out students who could stay in. And there are a lot of different reasons for that. One is, for a lot of students, they don't get experience in hands-on lab work or engineering work early on, and so they kind of think it's going to be too hard, and they leave.

But, I do think, if you look at the universities that have really focused on this, places like Carnegie Mellon, you can improve retention rates. I don't think it's impossible or even a mystery. I think part of the challenge is, you have to have incentives to do that. So, one measure that Congress could do would just be to simply require all research universities to report the number of students who apply to be a STEM major, the number that end up graduating, the numbers that switch out. If we just had better data on that, I think it would lead to some incentives for universities to, frankly, do a better job. Because there are very good programs at some universities around the country that focus on STEM retention, and they've been very successful at it. But, not every university is engaged in those programs.

Senator PETERS. Dr. Munson?

Dr. MUNSON. Yes. At the better universities, I think the retention rates are quite high. At the University of Michigan, 80 percent of the students who enter engineering as freshmen graduate in engineering from Michigan, the majority who don't transfer to some

other discipline. But, we're at the point now where we have equal numbers of liberal arts students transferring into engineering compared to the number of students leaving engineering. It's a bidirectional flow. A lot of times, we forget to talk about the students that transfer in the other direction.

I do recognize that some other universities, that they have tougher issues. Part of the issue is that, to succeed in engineering, you've got to be pretty darn good at math and science. And at my university, I have the luxury of lots of students who are good at math and science. And so, we don't have big issues. And in some other places, they probably struggle more.

Dr. WING. I'd like to address this, too. Thank you. Yes, at Carnegie Mellon University, we don't have those retention problems, primarily because of the structure in which majors are chosen at CMU. And we have a flood of people knocking at computer science doors, trying actually to get into the computer science major.

I think one of the problems is—as alluded by Professor Munson—students have to come to college prepared. They have to have the science and math behind them in order to take the college-level science and math courses to do well. And some students may not come as prepared.

The second is something that industry can address, which is, when a student is an undergraduate, he or she may not actually know, "Well, what am I going to do with this major?" And this is where industry can help—and we do this at Microsoft—by providing internships to undergraduates and giving them exposure to what it would be like to work in the field alongside an engineer or a scientist.

Dr. DROEGEMEIER. Just to add on that, I think preparation in K–12 is extremely important. Obviously, these disciplines require adequate preparation. I think one of the important things that universities are doing more now is advising their students. It's not OK, if you got, you know, a C in a math class, to just chuck the whole thing and say, "I'm going to become, you know, a whatever major, a non-STEM major." So, advising, sometimes you want to make the kid happy and keep the parents happy, but, at the end of the day, you're giving them bad advice if you say it's OK to be bad at math. Right? And so, that's something that's very important.

Undergraduate research, that hands-on engagement, many, many studies have shown that active, engaged undergraduate research can take kids that are not doing as well traditionally in a cohort, and really move them forward and help them succeed and graduate, where, otherwise, they wouldn't.

And then, finally, I think one of the challenges we have is, kids get into these disciplines, and they look around, they don't see people that look like themselves. And so, we have to really be careful and do a good job, when we're talking about broadening participation, to actually enact programs. And I think COMPETES Act is very sensitive to this, to look at how we holistically move the needle and the—on broadening participation. The new NSF INCLUDES program, I think, is one of the, really, most exciting things I've seen come around for a long time. And we spent hundreds of millions of dollars in this country trying to broaden participation of underrepresented populations. And we've done a pretty

bad job. The needle's not moving a whole lot. In some areas, it is. But, in computer science, the number of women there is still extremely low. And so, when kids get into those disciplines and those classrooms, sometimes they're really turned off by it, and they leave. And so, they're not counseled to stay in. So, it's really a multidimensional problem. It's not just one quick fix will fix it. We have to attack it from multiple dimensions.

Dr. MUNSON. I just wanted to add that Dr. Atkinson made an important point a few moments ago. And that is, early on in the curriculum at the university, whether it's computer science or in engineering, it's important to have some sort of design-based, hands-on kind of course, where students see how the material will be used. A lot of universities are doing that now, and those tend to be the places where they have the higher retention rates.

Senator GARDNER. Thank you.

And, just to follow up on, Dr. Wing, your comment on sort of teacher training. One of the comments that I heard throughout various of the roundtables we held was, teacher training and then, particularly those who may not be—have initially graduated with the type of training that a STEM field requires—maybe they went to class or college after they've been teaching for a while—and they were talking about how there's a special way to teach these courses, and then, after a while, it's so difficult that sometimes they revert back to a teaching method that isn't necessarily reaching out to the STEM in such a way. So, the—that they need to in order to carry out the education the best possible way.

So, what about teacher training and then ongoing mentorship within the private sector? How important is that? So—or, not, sort of, the private sector, but, I mean, how important is it to partner a teacher who has been trained to teach in a STEM field so that they can continue to have somebody in the STEM fields helping them along the way?

Dr. WING. This a great setup question for a program that Microsoft runs, called TEALS, where we have people in the company go to local high schools and work with teachers to help teach computer science and other STEM disciplines. And it is about not just training the teachers, but also about mentoring them and being available to them as the transition happens between their being a teacher in one discipline and their becoming a teacher in, say, computer science.

So, I completely agree with you. It's not just about training the teachers and then letting them go on their own, at least initially. Ongoing mentoring and advising has to happen as well.

Senator GARDNER. Dr. Wing, Dr. Munson, so when you're in the private sector, what's the earliest that you hope to reach somebody for Microsoft, hoping they get interested in, say, computer science? And, Dr. Munson, when you're looking at graduates, what's the earliest exposure that they've had to engineering or computer—the STEM fields when they come in and enter a degree?

Dr. WING. So, I—speaking as Jeannette Wing, who wrote a paper 10 years ago on computational thinking, I have always had this grand vision that everyone, starting from K through 12, will be exposed to computing concepts. Now, of course, I wrote that paper 10 years ago, not knowing how much progress we would have been

able to have made in 10 years. Realistically, speaking now as someone in industry who looks to the next generation for the workforce, minimally—minimally, every high school student should have access to computer science. Now, ideally, you will have been exposed to some of the ideas and some of the concepts before high school, say K–6, and so on. And there are computer science ideas that one can imagine talking about at those earlier grades. Can I give you one example?

For instance, in fourth grade, we teach long division to 9-year-olds. Long division—and specifically what we teach as long division to 9-year-olds it's just an algorithm. So, why don't we even use the word "algorithm" when we teach long division? And if we did, we would open up the minds of all 9-year-olds to something more than a way to divide one number into another to get a quotient and remainder.

Senator GARDNER. Dr. Munson.

Dr. MUNSON. We're very involved in K–12 outreach, probably more at the high school level than earlier years. We have a large effort in Center City Detroit, where we mentor 18 high school teams in first robotics. We have a few hundred almost 100-percent underrepresented minority students there, and almost every student that graduates from the program is going on to college. And so, that's a great example of a program that is working really well.

But, we worry about students that we aren't able to recruit into that program. And we feel like we're losing students at the middle-school level. And so, we're planning on increasingly getting involved at the middle school.

Senator GARDNER. Thank you.

Senator Peters.

Senator PETERS. I would like to take a look at the ecosystem that we talked about earlier, and how we fully develop this broad ecosystem that is not just academia, not just university research, but also industry, Federal Government, all of these partners working together.

Dr. Atkinson, you mentioned a small percentage of grants now go to the industry/academic partnerships that have been able to bridge some of those divides there. And yet, if we're going to truly move the innovation process forward, we have to break down all the silos, we've got to bring all these partners together. I know there are some real challenges, particularly if you've got private industry working in this ecosystem who want to protect some proprietary work and may feel uncomfortable working in an academic setting or having competitors in the process, as well. But, it seems to me that we have to figure out ways to have even more collaboration, going forward.

And I raise this question to—first, Dr. Munson, to talk a little bit about a program that I've seen at the University of Michigan that I think is very innovative, dealing with autonomous vehicles and the transportation work that's being done. Where you've got insurance companies, you've got all the major auto manufacturers, you've got suppliers, you've got academia, you've got NHTSA, Federal agencies working together, as to how that model works, how that could be a template for other work. And then maybe have the other panelists discuss if there are ways in our COMPETES Act

that we can help foster this kind of collaboration across all sectors and break down some of the barriers that just inherently exist.

Dr. Munson?

Dr. MUNSON. Yes. So, in the case of autonomous or driverless cars, we built a wonderful test track on our campus and took a year or so to put together a consortium of more than 60 companies. And, Senator Peters, as you noted, it includes companies beyond just the traditional OEMs in the automotive space. It includes suppliers, it includes communications companies and insurance companies and what have you. Each of those companies is putting significant money into the pot, so to speak, and funding what is—what we refer to as pre-competitive research. Those companies get to help choose what that research will be.

That said, we have very intensive partnerships in that space with a much smaller number of companies. Historically, we've been working very, very close with Ford. We—our teams of faculty and students actually work part of the time at Ford. Ford employees are over on our campus. We test cars, the Ford cars, the Ford autonomous cars, both on our campus and at Ford. So, that's a really close collaboration, and it gets really touchy, because then, when other companies may want to work with us—the most recent is Toyota, which is going to be now centering its driverless car activity in Ann Arbor—we can't really have that same set of faculty working with Ford work with Toyota at that same level of depth, because, you know, it's—it goes way beyond just filling out nondisclosure forms. We know everything. And I credit, though, Ford, for being willing to partner with us at that level. And the same thing's going to be happening with Toyota. Fortunately, we've been hiring a lot of faculty members in this area. We can kind of divide up our faculty members to do the really in-depth work.

Dr. ATKINSON. So, when you look at sort of the history of U.S. science policy, what you found was that, before 1947, industry funded a lot of university research. And then the Federal Government kind of came in, and industry went away. They've come back, to some extent, and I think getting that partnership to grow even more is critical.

When we look at what our competitor nations are doing, that's where they're putting their focus. When you look at the—what the Cameron government is doing in the U.K., they have a program called the Catapult Program, bringing industry and university together. They're investing over a billion pounds a year into that program. So, they're—a lot of countries are doing this.

I think one of the challenges that we hear, but I, frankly, don't think it is a real challenge, is somehow that that university research is separate from industry research, and there are all these conflicts of interest and problems. I think good management, which it sounds like you have, is able to solve that. There's very good studies that Denis Gray, at NC State, has done, who has evaluated the IUCRC program, and he finds that the science produced in that program is just as good as the science produced in other kinds of programs, but it's linked more to industry.

So, I think we could do more IUCRC programs. The manufacturing universities' proposal, the manufacturing universities' bill is an excellent way to do that. Expanding the NNMI program, the

National Network of Manufacturing Innovation—you—Senator, you talked about an environment. Well, the lightweight materials center that is doing that is—that's a key partnership. So, I think focusing more there is very, very important.

Dr. DROEGEMEIER. I'd like to add a couple of things.

This ecosystem, I think, is extremely important. And one of the things that I think we need to consider, and the COMPETES Act could look at is, How do we remove barriers? And I think one of the major barriers that we have with universities is how to work effectively with private companies.

Part—there are sort of three major issues. If you look at the research—R&D that's funded in this country, it's grown exponentially in the last, you know, 20 years or so. And private sector is—basically been responsible for that growth. And they now fund two-thirds of all the R&D in this country. The amount of that growth that has come to universities has been almost nil. You have to ask the question, Well, why? Why—you know, why are companies not going to universities to work with? And, number one, I think there's a perception that universities only do basic research. That's not true. In engineering and a lot of other fields, a lot of the work is very applied-type work or development-type work. It's deep scholarship. It's very creative. But, it's not studying atoms. OK? It's actually doing things that have—or that are sort of use-inspired.

The second point is that faculty—we—you know, our incentives and our reward models in universities are not aligned with the kinds of things we're talking about. Can you publish papers if—I work with a private company. As you mentioned, Senator Peters, if you have three companies working with a private—with a university, and they're all competitors with one another, do they feel comfortable that their interests will be protected?

The third thing is law, that—or policy within the IRS that you guys could really work on in COMPETES Act, and that is, it's an issue with regard to universities that have buildings that are debt service with tax-free bonds and that have limitations on the amount of private-sector activity that can happen in those buildings. Roughly, about 5 percent, I think, is the limit. There are two safe harbors for that. One of them is, if the private company wants to do intellectual property negotiation, you have to wait until the IP exists to negotiate the license. So, essentially, a private company comes to a university and says, "OK, I want to give you a million dollars to do this work for us," and you say, "That's wonderful." And they say, "What do I get from that?" You say, "You get a right to negotiate a license." "Well, what's it going to cost me?" "Well, we can't tell you, because we don't know what the value is." Well, that suggests that the universities are all about the license fees. Universities make very little off of license fees, for the most part. The value of working with a private company for universities is the upfront direct costs of funding: research, students, laboratories, post docs, grad students, things like that.

The second safe harbor is, it's basic research. OK? Well, if it's basic research, then it's in the public interest, right? And that's now what private-sector companies are about. So, these provisions in the tax line—in fact, Representative Lipinski, of Illinois, has introduced a bill in the House that sort of looks at fixing this prob-

lem. And I think—you know, universities are very reluctant to, you know, enter into these partnerships. And what this thing does is, it perpetuates this notion that, in the private sector, universities are hard to work with. And they are. But, it's not really necessarily their fault. They're bound by these revenue proclamations within the IRS tax codes that prevent them from negotiating the way that they would want to negotiate.

So, if we could remove some of those barriers, we could change the incentive models and change the culture of the universities to where they embrace working with private companies, and see it as a value proposition for higher education, I think we would come a long way toward really unlocking the potential of the industry/academic partnership that we talk about a lot.

You know, I like to say it this way. We're playing football with baseball rules. You see people say, "We've got to be more creative." No, we have to change the rules of the game. If we're going to play football, let's play football, and let's change the rules to football. Let's not kid ourselves that we're going to win the game by playing football with baseball rules.

Dr. ATKINSON. Could I just add one quick point, which—to build on Dr. Droegemeier's point? About 15 countries around the world now provide a more generous research-and-development or research-and-experimentation tax credit if you're partnering with a university. So, you get a more generous credit. The United States does the opposite. We actually penalize you. If you're a Microsoft or another corporation, and you're doing a partnership at any of these universities, the R&D credit actually penalizes you to do that. And we could at least make it—we should at least make it neutral so we're not biased between whether you do it in-house or with a university.

Senator GARDNER. Thank you.

I want to thank all of you for your time and testimony today. I really, truly appreciate this and look forward to putting forward a bipartisan bill soon that we can act upon and have signed into law.

The hearing of record will remain open for 2 weeks. Members are encouraged to submit any questions for the record that they have during that time. And I would ask, upon receipt of those questions for the record, if you would reply as promptly as possible.

And, with that, with the thanks of the Committee and on behalf of Chairman Thune, thank you for being here. This hearing is adjourned.

[Whereupon, at 12:03 p.m., the hearing was adjourned.]

A P P E N D I X

NEW ENGLAND INNOVATION ALLIANCE
20 NEW ENGLAND BUSINESS CENTER, ANDOVER, MA 01810

Advanced Fuel Research
Aerodyne Research
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TIAX LLC
Triple Ring Technologies
Triton Systems
V Squared Wind

Wednesday, May 11, 2016

The Honorable John Thune (R-SD)
United States Senate
Senate Committee on Commerce, Science, and Transportation

The Honorable Bill Nelson (D-FL)
United States Senate
Senate Committee on Commerce, Science, and Transportation

Dear Chairman Thune and Ranking Member Nelson,

Thank you for convening the hearing titled "Leveraging the U.S. Science and Technology Enterprise" and for establishing the Commerce Committee's bipartisan Innovation and Competitiveness Working Group, led by Senators Cory Gardner (R-CO.) and Gary Peters (D-MI.). As the Commerce Committee continues to explore potential legislation that will shape our national science and technology policy, we want to remind the committee of the economic impact that the Small Business and Innovation Research Program (SBIR) has on our country.

The New England Innovation Alliance is an informal association of senior managers from small high-technology companies in Massachusetts, New Hampshire, Vermont, Rhode Island, and Connecticut. It was founded in 2001 to provide a forum for exchanging experiences and challenges for small businesses primarily doing business with the US Government – including both R&D and product sales. Collectively, the members employ more than 1,000 scientists and engineers with more than $250 million/year in revenue.

Our member companies have leveraged SBIR investments to create commercial products that are sold worldwide as well as defense technologies used by our warfighters. In so doing, they have also created high value jobs and commercial activity in their communities.

The SBIR program represents America's seed money and has helped create new companies, excellent high technology jobs, and a great many publications and patents. The SBIR program funds concepts at very early stage where no other funding source exists. It allows the risk takers to retain and reap the rewards of their dedicated efforts. Ultimately the investment is returned through taxes. Recent studies by the National Academies and various federal agencies report the program's success. Every government dollar results in over $3 of revenue after Phase II.

The SBIR program has demonstrated its value over the past 33 years. As part of the Commerce Committee's work, there are several policy recommendations to consider

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that would make the SBIR program better and therefore improve our nation's overall science and technology policy:

- A long term charter or permanency for the program would allow for better agency planning and staffing.
- Increasing the allocation of agency S&T funds for the program would allow wider participation and focus funding on maturing successful technologies

We appreciate your leadership on this key issue and hope the Committee will increase the participation of small businesses as you explore ways to leverage government programs to expand, improve and better our nation's scientific and technology policy. Many of the policy recommendations referenced above are addressed by S. 2812 - The SBIR and STTR Reauthorization and Improvement Act of 2016 sponsored by Senators Vitter (R-LA), Shaheen (D-NH), Ayotte (R-NH) and Markey (D-MA) and supported by several other Members of the Senate Commerce Committee.

We urge your support in reauthorizing the SBIR program in the current congress.

Sincerely,

Mark G. Allen,
Chair, New England Innovation Alliance

PHYSICAL SCIENCES INC.
Andover, MA, Wednesday, May 11, 2016

Hon. JOHN THUNE (R–SD),
United States Senate,
Senate Committee on Commerce,
Science, and Transportation.

Hon. BILL NELSON (D–FL),
United States Senate,
Senate Committee on Commerce,
Science, and Transportation.

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Physical Sciences Inc. (PSI) is a small business research and engineering firm that successfully participates in several government scientific research programs including the SBIR program. PSI has transitioned many SBIR technologies all the way through to commercialization. For example, under NIH/NEI sponsorship, PSI, working with clinical researchers, developed a retinal tracking method permitting greatly improved eye examinations. We partnered with a leading eye equipment manufacturer, and they have sold 16,000 systems containing this technology over the last eight years producing over $1.2B in revenue, that are providing better eye care for tens of million Americans. Under EPA sponsorship PSI has developed a handheld LIDAR to detect natural gas leaks. For this technology, we partnered with a leading company in natural gas technology manufacturing and surveying. We have sold over 3,300 systems and a large fraction of American homes has been made safer using this technology. Many well-paying jobs have been created both for manufacturing this technology product and performing natural gas surveys. Under Air Force sponsorship we have developed critical optical components that are now integrated into aircraft systems. This is R&D in action to benefit our nation—reduced to practice and creating jobs.

There are many stages required for a new technology to reach the marketplace. It is essential to work with partners—each contributing their expertise along the path to successful product creation. Innovation often occurs where areas of expertise intersect. During a recent five year period our company funded collaborative research programs with over 50 different American Universities under STTR and SBIR programs, but also as part of other Federal and industrially funded development contracts. Small businesses are an excellent partner to work with Universities to transition their discoveries through development into the marketplace.

PSI seeks to find the best path to market for each technology developed under SBIR funding. We have manufactured and sold the technology directly into smaller uniquely specialized markets. Under NASA sponsorship we created accurate space simulation chambers that have been sold around the world, and offered testing services. Nearly every material that has been put into space has been tested in our chambers. Under Army SBIR sponsorship we have developed and sold sensors to detect chemical warfare agents remotely at distances permitting troop safety. Under Navy sponsorship we have developed fuel quality monitors for naval and commercial aviation. Under DNDO sponsorship PSI has implemented novel algorithms that vastly improve radiation sensor performance at screening portals critical to the security of our homeland. Another effort under Army sponsorship resulted in PSI developing a very-capable, small UAV to provide our warfighters and law enforcement situational awareness. Hundreds of these systems are now in use protecting American warfighters and American citizens.

In emerging technology areas we have sought external equity investment and created new companies. This has allowed PSI to leverage early government investment, attract private funding from Venture Capital and Private Equity partners and create new high paying jobs across several industries.

The SBIR program represents America's seed money and has helped create new companies, excellent high technology jobs, and a great many publications and patents. It is the envy of other countries, and its success has not been duplicated due to America's unique entrepreneurial culture. The SBIR program funds concepts at very early stage where no other funding source exists. It allows the risk takers to retain and reap the rewards of their dedicated efforts. The government and the agencies are truly patient angel investors. Ultimately the investment is returned through taxes. Recent studies by the National Academies and various Federal agen-

cies report the programs success. Every government dollar results in over $3 of revenue after Phase II.

The SBIR program has demonstrated its value over the past 33 years. As part of the Commerce Committee's work, there are several policy recommendations to consider that would make the SBIR program better and therefor improve our Nation's overall science and technology policy. A long term charter for the program would allow for better agency planning and staffing. Before the 2011 reauthorization, there were 14 short-term continuations that made it difficult for the agencies to execute the program and made it impossible for the small businesses to maintain staff and advance their technology. With the 2011 reauthorization, the SBIR program managers and staff at all the agencies have shown great dedication and commitment to making this good program even better—making ever more companies aware of this opportunity.

The Committee should also look at policies that would assist small businesses participating in the SBIR program to create a path to commercialization. For years many worthy technologies have ended at the conclusion of SBIR Phase II programs because the technology, although demonstrated, is not in a form recognized by a commercial company or by a mission agency as viable: At the end of Phase II it often has not been demonstrated outside-the-lab under real world conditions. This gap has become known as "The Valley of Death" for SBIR technologies. Too many promising technologies do not make it through to become viable commercial products. A good many receive some post-Phase II funding but it is too little, too fragmented, too restrictive. The Commercialization Readiness Program created in the 2011 reauthorization has begun to address this need. It is worthwhile to consider policies that increase the SBIR allocation and focus it on further maturation of promising technologies post-Phase II.

If our country is going to be successful in expanding scientific research and broadening economic opportunity, policy makers must look at ways of making scientific research programs more inclusive by drawing in a diversity of companies and nontraditional participants. We all understand that it is not easy doing business with the Federal Government. Recently there has been significant effort to involve nontraditional ventures and new companies in providing technology to address national needs. Instructions are complex. Submission is complex. Regulations are complex. A very large barrier to those new participants is the requirement for a government approved accounting system. The Committee should explore ways that will reduce the burden on both the companies and the government contracting officers so as to enable speedier contract award and more rapid advance of the technology. The innovators will spend more time on their technology rather than FAR compliance. Most importantly, this will encourage many new entities to participate not only in the SBIR program but across the wide range of opportunities to support our national needs.

I appreciate your leadership on this key issue and hope the Committee will increase the participation of small businesses as you explore ways to leverage government programs to expand, improve and better our Nation's scientific and technology policy. Many of the policy recommendations referenced above are addressed by S. 2812—The SBIR and STIR Reauthorization and Improvement Act of 2016 sponsored by Senators Vitter (R–LA), Shaheen (D–NH), Ayotte (R–NH) and Markey (D–MA) and supported by several other Members of the Senate Commerce Committee. The SBIR program is already one of the most successful in the government and deserves to play a key role in this discussion.

Sincerely,

B. DAVID GREEN, PH.D.,
President & CEO,
Physical Sciences Inc.

RESPONSE TO WRITTEN QUESTION SUBMITTED BY HON. JOHN THUNE TO DR. ROBERT ATKINSON

Question. In your testimony, you suggest that NSF should develop and implement metrics by which universities report various measures of entrepreneurship and research commercialization.

Can you discuss in more detail the kind of metrics you think should be collected, how to account for influencing factors like university size and geographic location, and how NSF could appropriately disseminate the data for public consumption?

Answer. Currently there is no real way to assess how well U.S. research universities are doing when it comes to transferring knowledge to the private sector for commercialization. This means we can't really assess whether universities as a group are making progress or not; nor can we assess which universities are leaders and which are laggards.

There are some data that are collected but it is inadequate and not combined into a single measure. NSF collects data from 895 universities on how much research funding from industry they receive. The Association of University Technology Managers (AUTM) collects data on technology licensing by industry, but this data is proprietary.

One solution to this would be to require NSF to compile a set of indicators for each research university/college that receives Federal research funding. The indicators should include: (1) money from industry for research (they already collect this); (2) university patent filings; (3) license disclosures and income when the technology is licensed to a firm in the United States; (4) jobs in academic faculty or student tech-related business start-ups; and (5) the number of agreements signed with business to allow the use of university technology.

If collected annually this would certainly help Congress and NSF understand longitudinal trends. It would also help compare leaders and laggards. Even without tying this data to any outcome it is likely that the simple desire of universities to want to rank well would encourage university leadership to adopt best practice tech transfer policies and practices.

It will be important with to benchmark this data to control for other variables. Clearly an institution like Johns Hopkins should have an advantage over say, University of Northern Illinois, because it receives a very large amount of Federal research. In other words, the measure should not be in absolute terms, but in terms of how well a university does in relation to the amount of Federal research dollars it receives. In other words, if a smaller research university receives a limited amount of Federal research dollars but does well in attracting industry R&D funding and generating licenses and start-ups that is what really matters. Given that it all else equal it is easier to commercialize technology in metropolitan than rural regions, these measures could be reported for several different geographic classes: for example, research universities in areas with less than 100,000 people, with 100,000 to 1 million, and above one million. Finally, any such effort should require NSF to report data in a timely way. For example, reporting on 2017 would need to be released by the end of 2018 (the chronic delay in the release of NSF data continues to degrade its usefulness).

After collecting this data NSF should make the data set available in machine-readable form so that a variety of other organizations (news media, professional and business organizations, academic researchers and others) could use the data to construct their own modified indicators. In addition, NSF should report the data so that all research universities are ranked on these variables with the amount of Federal funding as the denominator (*e.g.,* patents per 1 million Federal R&D support).

RESPONSE TO WRITTEN QUESTION SUBMITTED BY HON. STEVE DAINES TO DR. ROBERT ATKINSON

Question. Dr. Atkinson referred to the importance of the National Institute of Standards and Technology's (NIST) Hollings Manufacturing Extension Partnership (MEP) program. In Montana, the MEP is operated through Montana State University. I have heard from stakeholders that this relationship is working well in Montana. However it is imperative that the public and the private sectors can work collaboratively for this program to be effective. Would you please elaborate on how relationships can be facilitated between universities, the private sector, government, and others in programs such as MEP, Small Business Innovation Research (SBIR), and Small Business Technology Transfer (STTR)?

Answer. Fostering greater levels of partnership and collaboration between universities, industry, and Federal and state governments and the agencies therein (*e.g.,* MEP, SBIR, STTR, etc.) is vital to spurring greater levels of innovation, including

through technology transfer and the commercialization of new technologies developed in university laboratories. At the state level, many MEP centers have historically been focused with one-on-one project engagements with SME manufacturers to assist them in improving manufacturing processes or designing and developing new manufactured products. While the one-on-one SME manufacturer engagement remains the core of the MEP intervention, many state MEP centers are leveraging digital technologies to offer more Webinars, courses, and classes to all SME manufacturers broadly in a state across a broader range of topics, such as presentations by university researchers on new materials or manufacturing processes, the role of design and sustainability in manufacturing processes, or how to use cutting-edge digital tools such as high-performance computing-enabled computer-assisted design and engineering tools. In other words, the MEP centers are seeing themselves become the central hub, or delivery mechanism, for a comprehensive suite of services, some of it provided by the agency itself and some of it brokered by others, all designed to boost the competitiveness of SMEs. Legislation sponsored by Senators and Ayotte in the MEP Program Improvement Act of 2016 would increase program funding for MEP, expand its remit, modify the Federal cost share, and promote MEP center competencies with "automated manufacturing systems and other advanced production technologies, based on Institute-supported research, for the purpose of demonstrations and technology transfer."

The Federal Government could better facilitate states' efforts to tap into the vast treasure trove of technology that too often sits untapped on the shelves of state universities or research institutions. For example, draft legislation in S. 4047 would create a Federal Acceleration of State Technologies Deployment Program, or "FAST," a Federal funding strategy for accelerating the local commercialization of newly developed technologies by matching cash-poor state programs. The program would leverage Federal resources to match states' investments in their technology commercialization programs. Matching Federal funds would be available concomitant with a state's level of investment (prorated against state population with a maximum cap) in its technology commercialization programs. States would use the money for direct, merit-based project grants to existing SMEs or to startup companies looking to commercialize new products or technologies (with the expectation that a major source for those technologies would be ones currently sitting untapped at America's colleges and universities).

But, broadly, the core issue here relates to allocating (or directing) more funding to commercialization-oriented efforts. ITIF has suggested that Congress create a Spurring Commercialization of our Nation's Research initiative whereby Congress allocates 0.15 percent of agency research budgets to specifically fund university, Federal laboratory, and state government technology commercialization and innovation efforts. Such a program would be different than the STTR program (which funds small businesses working with universities.) Half of the funds would go to universities and Federal laboratories that could use the funds to create a variety of different initiatives, including mentoring programs for researcher entrepreneurs, student entrepreneurship clubs and entrepreneurship curriculum, industry outreach programs, seed grants for researchers to develop commercialization plans, etc.

A similar approach was embodied in Section 8 of the proposed Startup America 3.0 Act, which included a section titled "Accelerating Commercialization of Taxpayer Funded Research," which would have set aside 0.15 percent of Federal agencies' extramural research budgets from 2014 to 2018 to offer: (1) "commercialization capacity building grants" to institutes of higher education pursuing specific innovative initiatives to improve an institution's capacity to commercialize faculty research; and (2) "commercialization accelerator grants" to support institutions of higher education pursuing initiatives that allow faculty to directly commercialize research in an effort to accelerate research breakthroughs. Collaborative initiatives would be favored as would grants going to institutions of higher education (or other entities) with demonstrated proficiency in creating new companies.

Whichever mechanism is chosen, increasing the focus on commercialization and technology transfer would play an important role in bringing universities closer to startups and to the private sector.

Separately, the National Network for Manufacturing Innovation (NNMI) plays a pivotal role in helping industry, academia, and government work better together to create transformational technologies and build new products and industries. The nine Institutes of Manufacturing Innovation (IMIs) launched to date as part of the NNMI represent public-private partnerships that foster R&D and innovation in advanced manufacturing product and process technologies. The Institutes bring stakeholders together to solve pre-competitive industrial research problems; build industry technology roadmaps; provide testbeds and platforms; promote education, technical skills, and workforce development; and act as a conduit for SMEs in the supply

chain to engage Tier 1 OEMs. The NNMI represents a crucial fabric in America's technology ecosystem, and Congress should continue to support investment in building out the national network of manufacturing innovation institutes, ultimately trying to reach the goal of a network of 45 such centers.

Finally, the Small Business Innovation Research program represents one of the most successful innovation-promoting programs in the Federal Government. Despite the fact that the SBIR/STTR program accounts for less than 3 percent of the Federal extramural R&D budget, a recent ITIF study found that 60 percent of firms with fewer than 25 employees in the study utilized public grants through the SBIR in the creation of their innovations. Despite its strengths, there are programmatic reforms that could make SBIR an even stronger engine of commercialization activity.

First, SBIR Phase II awardees should be permitted to expend up to 5 percent of their Phase II funding on commercialization-oriented activities, such as market validation, IP protection, market research, and business model development, as Delaware Senator Chris Coons and Colorado Senator Cory Gardner propose in the new Support Startup Businesses Act, which establishes a pilot program allowing SBIR awardees to allocate no more than 5 percent of their grants for startup-related commercialization activities.

Second, as NACIE, the President's National Advisory Council on Innovation and Entrepreneurship, has proposed for how Congress could further improve the SBIR program: (1) Congress should significantly increase the allocation of Federal agencies' SBIR project budgets themselves toward supporting commercialization activities; (2) Congress should make commercialization potential a more prominent factor in SBIR-funding decisions. In particular, Congress could modify the criteria and composition of review panels to make commercialization potential a more prominent factor in funding decisions.

Response to Written Questions Submitted by Hon. Kelly Ayotte to Dr. Kelvin Droegemeier

Question 1. My state of New Hampshire, like your home state of Oklahoma, has tried to maximize research opportunities for students leveraging Federal funds to develop the "next generation" scientific workforce. How do we continue to develop science and technology expertise nationwide to preserve America's role as the leading innovator, and what is the economic benefit to our Nation when we develop scientific minds in all states?

Answer. Your question consists of two extremely important but related dimensions: First, the importance of a science and technology workforce to ensure the future of our Nation's leadership role in innovation, and second, the related benefits associated with making certain we engage talent in every corner of our Nation, not only those areas with the greatest population, wealth or infrastructure.

To the first part of your question, a decade's worth of data demonstrate the increasing pervasiveness and value of science and technology in the American workplace. Scientific and technological knowledge and skills are used in many more occupations than those traditionally thought of as science and engineering (S&E). In 2013, more than 13 million U.S. workers were officially classified as having a S&E or S&E-related occupation. Yet an estimated 17.6 million college-educated individuals, including many working in sales, marketing and management, reported that their job required at least a bachelor's degree level of S&E training. In addition, in the modern U.S. economy, many jobs that require less than a bachelor's degree still require science, technology, engineering, and math (STEM) skills. These "technical STEM" jobs, concentrated in the information technology (IT), health care, and skilled trades, are often among the best paying and most stable jobs available to individuals with a sub-baccalaureate education, and are distributed across all 50 states. There may be as many as 26 million jobs in the U.S. that require significant STEM knowledge and skill in at least one field. This represents nearly 20 percent of all U.S. jobs.

Given this high demand across the economy and across the country, 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, and to the second part of your question, the National Science Foundation (NSF, Foundation) 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. The

REU program has proven successful in developing student interest and persistence in science majors. Additionally, many universities, and virtually all research universities, now place strong emphasis on experiential learning in and out of the classroom, along with undergraduate research, in virtually all disciplines, with most institutions having formal offices of undergraduate research and specific credit and credentials for pursuing research during the baccalaureate degree.

Further, the vast majority of NSF research proposals include funding for undergraduate and/or graduate students, who participate as research assistants. Thus, whenever a project is funded by an Experimental Program to Stimulate Competitive Research (EPSCoR) grant from NSF, it is very likely that students will be gaining access to exceptionally high quality, hands-on science education and research experiences. Additional funding for students would be welcomed 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 science and technology leadership.

New Hampshire provides an excellent illustration of EPSCoR's powerful impact. The state's first EPSCoR project boosted research capacity in space science, environmental science and nanotechnology. EPSCoR provided funds to install a thermal-vacuum chamber at the University of New Hampshire (UNH) and at a facility at Dartmouth College, enabling participation in NASA missions. Nanoscale instruments installed at both institutions led to discovery of a compound that holds promise in the manufacture of flexible organic electronics, such as solar cells. The NSF award—which totaled $7.78 million over four years, enabled new research, leading to thirty-one more grants totaling nearly $52 million, spawned a spin-out company, Innovacene, Inc. that uses technology developed at UNH, built the world's largest wind tunnel, and resulted in 27 research partnerships with NH companies. In addition, the project's outreach programs reached 172 K–12 teachers and 3,814 students.

Yet, in spite of the important impact of EPSCoR on New Hampshire's contribution to our Nation's science and engineering research and education enterprise, EPSCoR is under serious threat. For the past two years, amendments have been offered on the floor of the House to eliminate EPSCoR, with the presumed argument that, if its resources are unavailable to all states, the program is not appropriate. This logic runs completely counter to the NSF Organic Act, which states that NSF shall not unduly concentrate its funding in any geographic region. Furthermore, and more importantly, the logic of the amendment means that some regions/states that are fully capable of making significant contributions to science and engineering research and education—like New Hampshire and Oklahoma—are hampered from doing so simply by virtue of their historically low research dollars garnered from NSF and other agencies. I therefore urge you to oppose the elimination of EPSCoR. And indeed, the Senate has seen fit to rename EPSCoR in the bill that emerged from this hearing and is to be congratulated for that thoughtful recognition of the value of EPSCoR.

Question 2. You identify several important governing principles: first, figuring out where government adds unique value, and second, getting government out of the way of our innovators instead of strangling creativity and enterprise with regulation. There is a conflict when taxpayer dollars fund work that is rendered inefficient through excess regulation. With these principles in mind, what are the best ways of reducing regulation to maximize the efficiency of our Federal dollars?

Answer. Both the National Science Board (NSB, Board) and the National Academy of Sciences (NAS) have issued reports in recent years—the most recent only a week ago in response to Congress—outlining steps that could be taken to reduce regulation, while still ensuring that taxpayer dollars are spent wisely and that human and animal subjects are treated ethically. Taking these steps is key to maximizing our Federal investments in scientific research. A survey conducted by the Federal Demonstration Partnership in 2012 found that 42 percent of faculty time related to conduct of federally-funded research at research institutions is spent on activities other than research, with 19.3 percent specifically related to administrative activities.

Among the principal recommendations of the NSB and NAS reports from the regulatory standpoint are:

- Harmonize grant proposal, submission, and reporting requirements across Federal science agencies. This includes establishing greater consistency in policies such as disclosure of financial conflict of interest and animal care as well as common, uniform guidance on things like formatting and electronic submission. Absence of harmonization leads to duplication of effort, multiple reporting of the same information in different formats, and submission of the same information on different schedules, thereby adding to administrative burden. Inconsistencies in financial audits are also a major contributor to administrative burden since,

when audit practices vary, scientists and institutions need to understand how to handle the variations. This can lead institutions to hold every transaction to the most stringent standard that may be applied, without regard to efficiencies. In harmonizing requirements across agencies, streamlining should also be a consideration, so that burdensome yet unnecessary requirements do not get instituted across the board. Pending legislation in both the House and the Senate calls for creating an entity under the aegis of the Office of Science & Technology Policy to regularly review regulations related to federally-funded research, identify outmoded, ineffective, insufficient, or excessively burdensome regulations, and coordinate new and existing regulations, policies, guidance, and application and reporting formats. This would be a very helpful step in promoting harmonization.

- Reform effort reporting requirements. Effort reporting was widely stated to be time-consuming for researchers and costly for institutions to administer, while yielding data that is not generally meaningful to evaluators. The NSF and National Institutes of Health Inspector Generals (IGs) are halfway through the Federal Demonstration Partnership pilot on payroll certification as an alternative to effort reports. Preliminary reports from the pilot suggest that this approach appears to reduce burden and IGs appear to accept the concept. It has now become part of the Office of Management and Budget's (OMB) uniform guidance. However, to ensure that payroll certification becomes standard, it would be helpful for Congress to recognize the acceptability of payroll certification.
- Address the increasing number of regulations related to human and animal subjects that add directly to scientists' workload but do not appear to improve the care and treatments of humans and animals. In particular, NSB recommends using a single Institutional Review Board to cover multi-site projects and eliminate continuing review for all expedited-minimal risk protocols.
- Re-examine applicability of certain safety and security requirements. A number of safety and security requirements that primarily target industry—but are applied to academic research settings—such as the Chemical Facilities Anti-Terrorism Standards and the Select Agent Program—should be reexamined and appropriate alternatives identified and implemented. Scientists report that the requirements for training; biosafety protocols; reports and certification; tracking use of chemicals; and frequent inspections are excessive, while not improving laboratory safety.
- Support the continuation and renewal of the Export Control Reform Initiative which has the potential to make significant improvements to regulations, oversight, and compliance, benefiting national security, the economy, and federally-funded university research.
- Greater collaboration among the IGs with agencies and universities, including resolving interpretation issues of agency policies with the agency prior to formal audits of research institutions; IGs broadly sharing model examples of agency and university initiatives that advance and protect the research enterprise; and publically sharing total costs (agency and institution) of IG audits of research institutions.

An additional important point, in the context of "getting the government out of the way," concerns a recommendation made in a recent American Academy of Arts and Sciences Report titled "Restoring the Foundation: New Models for U.S. Science and Technology Policy." I spoke to this issue during the hearing and want to reiterate its importance here. Specifically, the issue concerns so-called revenue proclamations in the Internal Revenue Code of 1986 (Section 141(b)) and the fact that corporate-funded research at universities is considered a "private business" activity unless the research is considered "basic or fundamental" (which the private sector rarely funds) or the sponsor must pay a competitive price for licensing once the technology resulting from the research actually exists. The latter is very problematic and impedes corporate-university partnerships because companies do not want to plan their business around a technology whose cost cannot be determined until it actually exists.

Modifications to this code have been proposed that would un-tie the hands of universities and allow them to negotiate license fees up front, thereby making corporate-university partnerships much more attractive to private industry. Evidence of the importance of this issue is found in the fact that, during the past 20 years, research and development funding in the U.S. has increased exponentially, with most of the increase coming from private industry (which now funds two-thirds of all Research and Development (R&D) in the Nation). It is disturbing that industry

funding for R&D at universities has remained flat, as a percentage, during this same time. Simply put, we are placing an unnecessary roadblock in front of private companies and discouraging them from accessing one of the most important assets available—the minds and facilities within our Nation's research universities.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. STEVE DAINES TO DR. KELVIN DROEGEMEIER

Question 1. As you know, Montana participates in the National Science Foundation (NSF) Experimental Program to Stimulate Competitive Research (EPSCoR) program. Montana State University and the University of Montana as well as other institutions have benefitted from the investments in research capacity enabled by this program. We often discuss the benefits of this program for the participating states and universities. Would you please elaborate on the national benefits of having a broad research community that expands into rural states and communities?

Answer. Every state, regardless of size, should have the capability within its borders to take on critical science and technology challenges that its citizens face. Smaller states are at a disadvantage in developing this necessary capacity. EPSCoR is specifically intended to build this capacity through merit-reviewed awards, by catalyzing additional growth by co-funding committed individual investigators, and by providing incentives for states to pay attention to their S&T needs and provide financial support to address those needs.

As you are well aware, Montana's EPSCoR program has developed nationally significant and regionally relevant science and engineering programs. The state's national leadership in biomedical and health related issues, nanotechnology, and study of life in extreme environments is in no small way attributable to EPSCoR. In addition, Montana's EPSCoR serves as a model for how to integrate economic development with university-based research and education. The program has also developed the state's human capital, which is essential to innovation. Between 2001–2011, EPSCoR enabled the hiring of 87 new faculty at Montana University System institutions, supported the studies of over 250 graduate students and the participation of over 1,300 undergraduates in EPSCoR research projects. In addition, since 2007, over 107 Native American tribal college students have participated in EPSCoR research projects.

A state's capacity to influence competitiveness also requires coordination, which is 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 entrepreneurs 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.

In addition to contributions to research and economic development, EPSCoR states, and especially their institutions of higher education, hire individuals educated in non-EPSCoR states. Many university presidents, provosts, and vice presidents for research in non-EPSCoR states received their advanced degrees from EPSCoR states, and the reverse also is true.

Question 2. While we have seen positive research conducted with NSF funds, we have also seen wasteful spending. Every dollar we invest in these programs should be used wisely and appropriately for research that will have meaningful benefits for society. During your tenure on the National Science Board, which fortuitously ended yesterday, what has NSF done to improve their vetting process and make sure they are good stewards of tax payer resources?

Answer. My twelve years serving on NSF's Board were profoundly rewarding. This agency has a long and distinguished history of promoting the progress of science and educating the next generation of innovators. We do this by supporting the best ideas and people this country has to offer. A quick look at our 60-plus year history shows the incredible results that have benefited our economy and quality of life. Of course, some of those benefits—to your point about "meaningful benefits to society"—are not immediately obvious and may not be for many years. Additionally, what is meaningful in the eyes of one person may not be in the eyes of another. And this takes us to the issue of merit review, which is the key to NSF's success in achieving its mission and its recognition, around the world, as the absolute gold

standard for funding research that has propelled the United States into an undisputed world leader in science and technology.

Merit review ensures that the choices of which ideas hold the most promise are informed by experts who best understand the science. This was a conscious, hard-fought-for principle at NSF's founding and it has been evaluated and refined since 1950. The principles and procedures of the Foundation's merit review system has been emulated by many other nations, who strive to duplicate NSF's peer review and grants management processes in hope of duplicating our success.

As NSF's governing body, the NSB annually reviews and, as needed, revises these processes to ensure our investments offer maximal value to the Nation. During my tenure on the Board, we conducted a two-year review of the Foundation's merit review criteria and the methods by which the reviews are implemented. The resulting report, *National Science Foundation's Merit Review Criteria: Review and Revisions,* concluded that the agency's Intellectual Merit and the Broader Impacts criteria remain appropriate and critical to its mission.

The Foundation's current merit review system, often referred to as the gold standard for assessing research proposals, has served the Nation exceptionally well. Recent legislative proposals to fundamentally alter NSF's merit review system by restricting NSF awards to a narrow subset of national goals or to projects where specific outcomes can be predetermined will undo the globally admired qualities that have made NSF so valuable to the Nation. Confining scientific inquiry to immediate or obvious application instead of scientific promise will undermine the unique strengths of the NSF system. For this reason, I am heartened that the initial version of the bipartisan Senate COMPETES bill reaffirms NSF's merit review system.

Despite its track record of success, NSF is always looking for ways to improve its processes—its transparency and accountability—and ensure sound stewardship of tax payer dollars. NSF Director France Córdova and her team have achieved great results to date in this effort, which include implementing new policies to enhance transparency and improved communication about the research the agency supports, and reexamining NSF's management of large projects and facilities.

Specifically, NSF has changed its policy vis a vis award abstracts and titles, clarifying to staff and the broad scientific community the need to communicate clearly and explain how a research project serves the national interest, as stated by NSF's mission: "to promote the progress of science; to advance the national health, prosperity and welfare; or to secure the national defense." As part of this effort, the agency now provides resources and training to its program directors to help them improve the clarity of award abstracts and titles. The agency also refined the roles and responsibilities of its division directors in merit review and now provides interactive training to new division directors when they begin working at the agency. Director Córdova reached out to the broad scientific community to inform it of NSF's new steps to enhance transparency and accountability, including its responsibility to clearly describe projects and justify the expenditure of public funds. This included an update to NSF's Proposal and Award Policies and Procedures Guide.

NSF is also working to strengthen its management of large projects. The recent National Academy of Public Administration (NAPA) report, *National Science Foundation: Use of Cooperative Agreements to Support Large Scale Investment in Research,* is proving a timely tool to improve NSF's oversight of large facilities. NSF Senior Management and NSB jointly commissioned this report, which identifies areas where NSF can improve and are in general agreement with the Panel's recommendations.

The Foundation has begun acting on the NAPA report. Several of the recommendations relate to specific business practices; for instance, retaining control of a portion of contingency funds, dealing with exceptions to recommendations from pre-award cost analyses, and expectations for awardees regarding Government Accountability Office (GAO) best practices. The Board concurred with the Director's plans to implement these recommendations, and will conduct oversight to ensure accountability.

A second class of recommendations relate to oversight, accountability, and stewardship. The Foundation is approaching these recommendations holistically, viewing the NSB, Major Research Equipment and Facilities Construction Panel, and Office of the Director as a system that the NAPA Panel recommendations can improve.

Among the work in progress:

- A consolidated, facilities-related website is being developed to support NSB and Senior Management decision-making.
- NSB and NSF are working jointly to clarify and codify roles and responsibilities related to the management and oversight of large facilities, in part to sustain

working relationships across transitions in Board membership and NSF leadership.

- NSF is adding project and financial management expertise to criteria for the selection of external reviewers, examining skill requirements for program officers and budget offices involved with large facilities, and building capacity in the LFO.
- NSB is continuing efforts to diversify the Board by adding financial and project management expertise as desired criteria for new members it recommends to the President in order to enhance NSB's oversight and stewardship of these large investments.

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