

**RESEARCH AND INNOVATION:
ENSURING AMERICA'S ECONOMIC
AND STRATEGIC LEADERSHIP**

HEARING
BEFORE THE
SUBCOMMITTEE ON SCIENCE, OCEANS, FISHERIES,
AND WEATHER
OF THE
COMMITTEE ON COMMERCE,
SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE
ONE HUNDRED SIXTEENTH CONGRESS
FIRST SESSION

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SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION

ONE HUNDRED SIXTEENTH CONGRESS

FIRST SESSION

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RESEARCH AND INNOVATION: ENSURING AMERICA'S ECONOMIC AND STRATEGIC LEADERSHIP

TUESDAY, OCTOBER 22, 2019

U.S. SENATE,
SUBCOMMITTEE ON SCIENCE, OCEANS, FISHERIES AND
WEATHER,
COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION,
Washington, DC.

The Subcommittee met, pursuant to notice, at 2:15 p.m. in room SD-562, Dirksen Senate Office Building, Hon. Cory Gardner, Chairman of the Subcommittee, presiding.

Present: Senators Gardner [presiding], Wicker, Sullivan, Scott, Baldwin, Blumenthal, Peters, and Sinema.

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

Senator GARDNER. I'll call this hearing to order. Thank you for being here today and thanks to the Ranking Member, Ranking Member Baldwin, for joining me and leading this hearing today.

Today's topic is about American competitiveness and the importance of investing in our Nation's research and development footprint.

In August, President Xi Jinping announced that Shenzhen, a city known as China's own Silicon Valley, would be named as the fourth major national science center in the country. That designation carries with it Beijing's hefty investments in expanding the already growing research and development initiatives in Shenzhen and further pushes China forward on the scientific front.

It's no surprise that President Xi selected Shenzhen for this new project. Shenzhen is a City of more than 12 million people and home to infamous Chinese tech and telecom companies like ZTE and Huawei.

Futuristic skyscrapers crowd the horizon and millions of scientists and technology employees are working around the clock to try to make China the new world leader in research and development and technological advancement.

As President Xi made this August announcement for science in China, violent protests raged in Hong Kong, just a few feet across the river from Shenzhen. The Mainland has been working to stifle democracy in Hong Kong at the same time they've been investing in gleaming cities, like Shenzhen.

This is the current Chinese Communist model, advancement through repression, investment through confiscation, science through decree.

Imagine a world where China discovered the latest and greatest innovations. It's a world where budding scientists and entrepreneurs would flock to Shenzhen and Quanzhou over San Francisco and Boulder. It's a world where free thinking and public-private partnerships would give way to the party line and centralized bureaucracy.

Ultimately, it's a world that would deprive the United States of our reputation around the globe as the scientific innovator and chief and strip us of a major driver of our economy.

In Colorado, our more than two dozen Federal labs contribute nearly \$2 billion annually to the state and those labs have put nearly 8,000 Coloradans directly into high-paying jobs. Coupled with significant investments from the National Science Foundation, the Department of Energy, and private technology and innovation companies, among others, the research economy is alive and well in Colorado and across the Nation.

The need to strengthen the U.S. research and development enterprise is what led me to introduce, along with Senator Peters, The American Innovation and Competitiveness Act.

Over the course of the last 18 months, our Innovation and Competitiveness Working Group convened discussions with academia, scientists, innovators, entrepreneurs, and industry to discuss what was working in U.S. science policy and what was not.

Throughout this process, we held to the goal of a bipartisan solution to these issues and had the outstanding support of this entire committee. At the end of the day, we were left with a bipartisan package that reaffirmed the importance of science, research and development, to the United States.

We made it clear that, yes, these issues do merit consistent Federal attention and that, yes, it can still be done in a bipartisan fashion.

I'm looking forward to starting another conversation about what it will take to keep American competitive and ensure that the next generation—the next generation—the next great breakthrough happens right here in the United States.

I'll turn to Senator Baldwin for her opening statement.

**STATEMENT OF HON. TAMMY BALDWIN,
U.S. SENATOR FROM WISCONSIN**

Senator BALDWIN. Thank you, Chairman Gardner.

I'm really very delighted that you're holding this important hearing and for your leadership supporting Federal research and innovation.

I want to thank all of our witnesses for joining us here today to share your perspectives, and I want to extend a special welcome to Chancellor Rebecca Blank from my home state of Wisconsin. I'll be introducing you a little bit later.

My grandfather was an NIH-funded scientist at the University of Wisconsin and I grew up visiting his lab and hearing about the pioneering work that he was doing to understand metabolism at the cellular level.

Earlier this month, I had the opportunity to visit the Morgridge Institute for Research at UW—Madison. Chancellor Blank welcomed me there and I got a chance to meet with researchers who are continuing to build on the work that my grandfather began in the late 1940s and early 1950s.

The Federal investment in his research made more than 70 years ago are still paying dividends. That visit was a powerful reminder to me of the critical and lasting role the Federal Government plays in our research ecosystem.

When my grandfather came to UW—Madison, our Nation was on the cusp of enormous scientific and technological accomplishments in computing, in robotics, in space exploration, medical science, and so many other areas.

The United States led the world in no small part because of our sustained investment in research. This has paid enormous dividends even today, but we can't maintain that role as a global leader without continuing to make these critical investments, and we have a lot more competition today, as the Chairman shared, particularly from China.

The United States' share of global research and development expenditures has declined from 37 percent in the year 2000 to 26 percent in the year 2015. While our R&D spending remained the largest, China was literally nipping at our heels with 21 percent of the global share.

In order to stay ahead, we absolutely have to strengthen our research investments. As a member of the Appropriations Committee, I've been proud to support better and stronger investments in the National Institutes for Health.

I look forward to seeing similar growth in funding for the National Science Foundation and other Federal research agencies.

But we cannot rely on increased investment alone, and I look forward to hearing from our panel about what else we can do to make those Federal research dollars work better. We should identify administrative and other barriers that limit the return on Federal investment in university research. We need to strengthen the partnership that encourages private sector research and we have to do more to help translate federally funded research into commercial applications that drive innovation and economic growth.

However, strengthening research investments is only part of the solution. I am concerned that we are failing to develop the STEM workforce our Nation needs to stay competitive.

To put it simply, our STEM jobs pipeline is leaky. To begin with, the United States has not kept up with other nations regarding K through 12 STEM education with our country ranking in the middle of advanced economies in producing high-achieving STEM students.

Even where we are making progress on STEM workforce development, we continue to see significant under-representation of women and minorities in these fields. Women comprise just 29 percent of the STEM workforce and underrepresented minorities make up just over 15 percent.

It is not just a question of equity. We are failing to tap an enormous resource that can contribute to our competitiveness.

At every step from K through 12 participation to undergraduate and graduate programs to entering the STEM workforce, we lose more and more women and minorities. We have to find more ways to open up STEM opportunities and help individuals from all backgrounds move successfully into the STEM workforce.

Finally, I believe that we must make more opportunities available to the next generation of researchers. In 2016, I championed legislation that directed NIH to focus on young researchers and I hope that we will consider similar efforts at NSF and other Federal research agencies.

It is yet another way we can ensure future generations will have the tools to keep the United States a leader in global innovation and again I want to thank the Chairman for convening today's discussion.

I look forward to hearing from our distinguished panel.

Senator GARDNER. We're going to have a couple of introductions of the witnesses today. Of course, we're honored to be joined by the Full Committee Chairman, Senator Wicker.

I'll turn it over to you, Senator Wicker.

**STATEMENT OF HON. ROGER WICKER,
U.S. SENATOR FROM MISSISSIPPI**

Senator WICKER. Well, I want to thank Chairman Gardner and Senator Baldwin for their leadership in this hearing and the Committee as a whole.

I think it's OK to say that we, all three, are delighted to welcome our former colleague, former Representative Matt Salmon, who is in the hearing room today, assisting with Arizona State University. Matt, it's always good to see you and glad to have you back in Washington.

Research and innovation and job creation are going well in Colorado and Wisconsin and I'm proud to say that Mississippi is playing a role and has played an important role over the years and in that regard, it's so great to welcome Dr. Shaw from Mississippi State University.

Mississippi engineers and scientists were pivotal in the first moon landing. It goes back that far and the entire Apollo Program. It was the Stennis Space Center that tested the Saturn V Rocket and deemed it ready and worthy of setting forth to the Moon. So we've been at this a long time.

Dr. David Shaw is one of the scientists in Mississippi who continues this legacy, pushing the boundaries of knowledge every day.

Drones fly over our state of Mississippi and help map floodwaters. Super computers generate more accurate weather forecasts than ever before and professors and students use artificial intelligence to test driverless cars for off-road use, and one such MSU innovator is Dr. David Shaw. So we welcome him.

This hearing is an opportunity for him and for the rest of us to examine the role of science and technology in our current and future economy. Everywhere we look, research and innovation is shaping the future of our lives. Support for research and innovation is critical to maintaining our country's global competitiveness.

So, Mr. Chairman, thank you for your leadership, and I look forward to a great discussion.

Senator GARDNER. Thank you, Mr. Chairman.

And with that, I'll turn to Senator Baldwin.

Senator BALDWIN. I am pleased to welcome Dr. Rebecca Blank, Chancellor of the University of Wisconsin—Madison to our panel.

Dr. Blank has served as Chancellor since 2013. Previously, she served as Deputy Secretary and Acting Secretary of Commerce in the Obama Administration and was a member of the Council of Economic Advisors under President Clinton.

She's also served as Dean and Professor of Public Policy and Economics at the University of Michigan, as a faculty member at Northwestern and Princeton Universities and as a Fellow at the Brookings Institution.

Chancellor Blank is an internationally respected economist who now leads a public university that regularly ranks as one of the top research institutions and largest recipients of Federal research dollars in the country.

I look forward to hearing your insights today, Dr. Blank, welcome, and "On Wisconsin!"

Senator GARDNER. Thank you.

Senator Sinema for an introduction.

**STATEMENT OF HON. KYRSTEN SINEMA,
U.S. SENATOR FROM ARIZONA**

Senator SINEMA. Well, thank you, Chairman Gardner and Ranking Member Baldwin.

I'm not a member of this subcommittee. So I very much appreciate the courtesy to allow me to introduce my friend and distinguished Arizonan, Dr. Panchanathan, who is testifying today.

Dr. Sethuraman Panchanathan, who goes by Panch, thank you for that,—

[Laughter.]

Senator SINEMA.—has an impressive list of accomplishments and accolades over his distinguished career as a world-class scientist, innovator, educator, and leader.

He's a Chaired Professor and the Executive Vice President and Chief Research and Innovation Officer at Arizona State University, which U.S. News and World Reports has ranked for the last 5 years as the most innovative university in the United States. Thanks to his leadership, ASU is also the fastest-growing research university in the United States.

Panch's own research focuses on human-centered multi-media computing, haptic user interfaces, computing technologies for enhancing the quality of life for individuals with disabilities, and machine learning for multimedia applications.

He has published more than 500 papers in refereed journals and has mentored nearly 150 graduate students, postdocs, research engineers, and research scientists.

In recognition of his contributions, President Obama appointed Panch as the first Indian American to serve on the United States National Science Board. He was also appointed by the former Secretary of Commerce to the National Advisory Council on Innovation and Entrepreneurship.

In Arizona, he serves as Senior Advisor for Science and Technology to Governor Doug Ducey.

Panch has dedicated his life to public service through the advancement of education, science, technology, and innovation to address challenging issues in Arizona, the United States, and across the globe, and personally, I'm glad to know him and count him as a friend.

Panch, thank you for your tireless work and for representing Arizona State University and the State of Arizona. We are so grateful for your testimony here today.

Thank you, Mr. Chairman.

Senator GARDNER. Thank you, Senator Sinema, and thank you for introducing a name that I was afraid I would just totally slaughter. So, Dr. Panch, we're glad you're here. Thank you.

Senator SINEMA. I practiced.

Senator GARDNER. Very good.

And I am going to introduce Dr. Souvaine. Thank you very much for being here.

Dr. Souvaine is the Chair of the National Science Board where she has previously served as Vice Chair and Chair. Her tenure includes professorships at both Rutgers University and Tufts University, receiving her Ph.D. from Princeton University.

Dr. Souvaine, thank you so much for being here today, and everybody else on the panel has spoken.

Senator Peters, I don't know if you want to say anything up front.

Dr. Souvaine, we'll go ahead and start with you since you patiently waited and go down the panel. Please limit your testimony to 5 minutes. Your entire statements will be submitted for the record.

STATEMENT OF DIANE SOUVAINE, Ph.D., CHAIR, NATIONAL SCIENCE BOARD, NATIONAL SCIENCE FOUNDATION

Dr. SOUVAINE. Chairman Wicker, Chairman Gardner, Ranking Member Baldwin, and Members of the Subcommittee, thank you for the opportunity to talk with you today.

I want to begin by saying how much we appreciate the long-standing bipartisan support that Congress and this committee has shown for NSF.

Chairman Gardner, for me testifying before your committee today is propitious. It was just a month ago that the Board visited Boulder and had a chance to visit three outstanding NSF facilities all within a few miles of each other. We visited NEON, the National Solar Observatory, and NCAR, and came away quite impressed.

Federal investments in fundamental research drive innovation because only the Federal Government can make strategic long-term commitment to creating new knowledge. This is the seed corn for the entire U.S. science and engineering enterprise, a global competitive advantage and the starting point for over half of GDP growth since World War II, yet we no longer live in the world of Vannevar Bush, in which American leadership and S&E was almost inevitable.

The world has changed, and while science is the endless frontier, we're not the only explorers. Research is now a truly global enterprise.

We should react to this with excitement, not fear. We are well positioned to thrive if we again embrace discovery and exploration and lean into the advantages that have made us so successful.

First, we need to compete both with intangibles and money. In recent years, both the private sector and Congress have responded to our peers worldwide with increased investment, including in NSF. For our part, we are grateful for Congress and the wisdom of Congress.

This upward turn is not enough to keep up with the accelerating pace of research. Based on current trends, the Board predicts that China will overtake us in R&D investments this year, if they have not already done so.

Between 2000 and 2017, while global investments tripled, NSF's funding rate fell from 33 percent to 21 percent, leaving billions of outstanding merit-reviewed ideas unfunded.

Research areas, like AI and quantum computing, are now ripe for an explosion of public and private investment in part because NSF supported early stage research in these fields years ago. At its core, a central mission of NSF is to ask what is the next big thing? So it's also worth asking while we still lead in fundamental research are we leaving the next Google, LIGO, or Kevlar already on the cutting room floor?

How many budding researchers see a foreign talent program as the only option for pursuing the work they love or see no option at all?

As you consider reauthorizing our science agencies, I encourage you to confront this directly. What do our agencies need to accomplish their missions? What does our country need to retain preeminence in science and engineering?

Second, we need to educate our own people and continue to attract and retain the best and the brightest from around the world. Recruiting the next generation means dispensing with outmoded stereotypes of scientists and engineers and doing more to diversify our STEM-capable workforce. No zip code or demographic group should be left out of the knowledge economy, and we need all of our domestic talent if we want to discover, invent, and innovate in this era of globalized science and engineering.

To this end, we must improve STEM education in the U.S. from K-12 through higher ed. We need to remember that education is the public good and that public universities and colleges have special role to play in providing access to high-quality STEM education to students in every state and even as we work to build our domestic STEM-capable workforce at all levels, it is equally critical that we continue to welcome curious, creative, and ambitious researchers from overseas.

Finally, we should recognize that America has not led with dollars alone but with our culture and our values. We should reaffirm our unambiguous commitment to the highest ethical and technical conduct of our research, leading the way in open worldwide collaborations, open publication, and archiving data for public use.

The U.S. should remain confident in its conviction that behavior as a model citizen in the global community and will serve as an example for others to emulate and a magnet for the world's best minds. This does not mean naiveté.

We must protect our national security, but I firmly believe that if the U.S. continues to conduct its science and engineering enterprise consistent with the principal traditions that have yielded 70 years of success, the benefits we realize from nurturing a global community of similarly principled partners will far outweigh any losses suffered as a result of the openness that we champion.

In conclusion, this is our ask: Be fearless. Let's not merely react to anxieties from global competition, concern about security threats or angst about constrained budgets. Instead, let's ask how can we lead the next era of science and engineering and remember the can-do attitude that defines America to ensure our continued preeminence in research and innovation. Let's unleash our strengths, a spirit of exploration, of wonder, of discovery, coupled with the willingness to take risks and an emphasis on freedom and individual creativity because the best way to lead the future is to invent it.

Thank you for your time, and I look forward to your questions.
[The prepared statement of Dr. Souvaine follows:]

PREPARED STATEMENT OF DIANE SOUVAINE, PH.D., CHAIR,
NATIONAL SCIENCE BOARD, NATIONAL SCIENCE FOUNDATION

Science has long been at the heart of the American experiment. "An investment in knowledge always pays the best interest," noted Benjamin Franklin, and the revolutionaries who founded our Nation and enshrined the promotion of "the progress of science and useful arts" in the Constitution. Since World War II, advancements in science and technology have driven 85 percent of our economic growth, underpinned our national security, and transformed nearly every aspect of Americans' daily lives. New technologies built on federally-funded discovery research have led to new businesses, revolutionized health care, and created the mobile, digital world.

Our preeminence has not happened by chance. Sustained, bipartisan commitment to investing in fundamental research has played a key role in establishing and maintaining our innovation enterprise. As we make the investments our country needs to compete in the 21st century global economy, we must renew our commitment to strengthening this key component of our national infrastructure and ensuring that we are not technologically surprised in key areas like quantum computing and artificial intelligence. Collectively, we must do this because the world has changed, and our country has changed. We no longer live in the world of Vannevar Bush, in which American S&E leadership was almost inevitable, or even on the edge of a gathering storm. Research is now a truly global enterprise, more connected, complex and nuanced than a "storm," with opportunities everywhere and humanity's collective knowledge growing exponentially. This is a brave new world, and while American preeminence is not assured, I think we should react with excitement, not fear. We are well positioned to compete, collaborate, and thrive.

The freewheeling creativity and entrepreneurial ethos that infuses our researchers is the "secret sauce" of America's scientific and engineering (S&E) enterprise. A wonderful example of this ethos can be found in the story of this year's Nobel Prize in Chemistry. After arriving in the U.S. to take up a postdoctoral fellowship at Stanford University, Dr. Stanley Whittingham's research in fundamental chemistry focused on the phenomenon of intercalation in solid materials. His work led him to propose that these materials could be used as electrodes in powerful batteries. Using superconducting materials and lithium, he invented the rechargeable lithium battery while working as a research scientist at Exxon, which was interested in developing alternatives to gasoline-powered vehicles during the oil crisis of the 1970s. Dr. Whittingham was granted the original patent on the concept for this type of battery, and his foundational research, developed further by his co-laureates, ultimately led to the invention of rechargeable lithium-ion batteries—which now power everything from industrial technologies to the mobile phones we all hold in our hands.

This story encapsulates many of the strengths of our Nation's S&E ecosystem—support for fundamental science from both the Federal Government and the private sector, welcoming of talent from around the globe, and giving the best minds the freedom to explore new frontiers and see where discovery leads them. The freedom

of inquiry enabled by Federal support for fundamental research through NSF and other government agencies has led to surprising new knowledge that has advanced our Nation in unexpected, unpredictable ways. As President Ronald Reagan noted, “The remarkable thing is that although basic research does not begin with a particular practical goal, when you look at the results over the years, it ends up being one of the most practical things government does.” The Federal Government is key to these endeavors, because it can make a strategic long-term commitment to creating new knowledge. History has shown that taking risks on creative researchers and bold ideas has paid off time and time again, with all sectors of our knowledge ecosystem—universities, government laboratories, industry—partnering to drive innovations.

So, this is our “ask” for this committee: *Be Fearless*. Let us not merely react based on anxieties about increased global competition, security threats, or current budget limitations. Instead, ask how we can grow our economy, lead the next era of science and engineering, remember the “can-do” attitude that defines America, and recommit to the partnerships among governments, universities, and private industries that has driven our success. Let us unleash our strengths—a spirit of exploration, of wonder, of discovery; coupled with a willingness to take risks and an emphasis on freedom and individual creativity—to ensure America’s continued preeminence in research and innovation in the 21st century. *Because the best way to lead the future is to invent it.*

U.S. Research and Innovation in the Global Context

Since 2000, global research and development (R&D) investments have tripled, reflecting increased competition in knowledge-intensive industries and recognition of the crucial role R&D plays in addressing global health, security, and environmental challenges. NSB’s forthcoming *Science & Engineering Indicators 2020* report confirms a trend that NSB has observed for several years: while the U.S. remains a leading player, other countries have seen the benefits of investing in research and education and are following our example.¹ The world of R&D performance, historically centered around the U.S., Western Europe, and Japan, has been shifting toward East and Southeast Asia.

While China is not the only story, it continues to exhibit a dramatic R&D growth trend. In 2018, the NSB issued a statement noting that China would likely surpass the U.S. in total R&D expenditures by the end of 2018. The most recent data, from 2017, show that while there was higher growth in U.S. business R&D than previously projected, the trend lines in Figure 1 suggest that China either has passed us already in R&D expenditures, or will by the end of 2019.

¹National Science Board (2020). “Research and Development: U.S. Trends and International Comparisons,” *Science & Engineering Indicators 2020*, forthcoming.

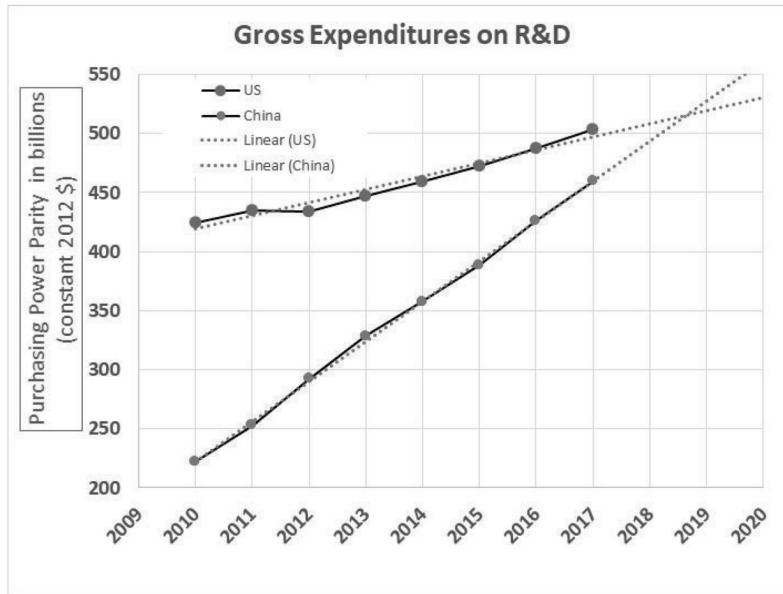


Figure 1: Gross Expenditures on R&D for the U.S. and China

Amid this dramatic growth in China's R&D investment, it is crucial to note that the U.S. maintains a significant advantage in *basic* research—which is the seed corn for our entire S&E enterprise. In 2017, the U.S. invested \$92 billion in basic research; China comes in a distant second, investing \$27 billion. While U.S. business sector investment in total R&D has recently grown faster than the Federal Government's investment, the lion's share of their investment has been on the applied and development side. In the U.S., 42 percent of *all* basic research is funded by the Federal Government, about half of which is performed at higher education institutions.

To produce results, R&D investments must be coupled with building a highly skilled, STEM-capable workforce, including everyone from associate's degree holders to PhDs. Today, we are seeing changes in S&E employment driven by international opportunities and competition, and by disproportionate growth in the number of jobs at all levels that require STEM skills. As of 2017, nearly 21 million workers with at least a four-year degree say that their job requires a "bachelor's level" of STEM expertise—and the vast majority of these workers (71 percent) are employed by the business sector, the cornerstone of the Nation's economic competitiveness.

These numbers do not include the more than 17 million people who use S&E skills in their job but do not have a bachelor's degree. As highlighted in the NSB's new report, *"The Skilled Technical Workforce: Crafting America's Science and Engineering Enterprise,"* these skilled technical jobs pay well, are found across the U.S., and are vital to the health of local economies as diverse as Detroit, Michigan; Florence, South Carolina; and Baton Rouge, Louisiana.² These individuals, who account for more than 50 percent of all workers in many of America's advanced industries, bring digital, math, and coding skills to work as auto mechanics, health care technicians, electricians, welders, computer systems analysts and administrators, and operators of "smart" infrastructure. Skilled technical workers are also critical to our Nation's S&E infrastructure, for instance in building and maintaining the miles of high vacuum pipeline and two-story banks of air filters that make the Laser Interferometer Gravitational-Wave Observatory (LIGO) work.

Foreign-born individuals have long been major contributors to our S&E enterprise. As of 2017, over 40 percent of our doctoral-level S&E workforce was foreign-

²National Science Board (2019). "The Skilled Technical Workforce: Crafting America's Science & Engineering Enterprise," NSB-2019-23.

born,³ and over half of the doctoral degrees in engineering, computer sciences, and economics were earned by international students on temporary visas.⁴ Highly skilled S&E workers have become increasingly mobile and nations have adapted their immigration policies to make it easier for these valued workers to relocate and work in their countries. At the same time, the U.S. share of worldwide internationally mobile students has declined slightly, even as the number of these students has risen dramatically worldwide. These changes indicate an accelerating competition for globally mobile talent. As more countries offer their students reasons to stay in their own country for their education or to return home after earning a degree, the U.S. could face a shortage in a critical segment of its workforce.

Looking to the Future

Why is U.S. preeminence in S&T so important? From quantum computing to artificial intelligence to the data revolution, scientific advancements come with both opportunities and risks. To mitigate those risks in an increasingly competitive world, it is essential that we stay at the forefront of science and cutting-edge research and maintain a strong economy. The past has shown that investment in basic research now will give us the keys to meeting the security, health, and economic challenges of the future—challenges we know will arise but whose nature we cannot predict.

We know that China and other nations are actively working to lead in research areas that hold enormous promise for revolutionizing our world, such as artificial intelligence (AI) and quantum computing. The White House and Congress are stepping up to meet this challenge, with increased focus and investment in key areas of S&E research and development. With sustained Federal investments, the Administration is advancing U.S. leadership in Industries of the Future: AI, quantum information sciences, 5G/advanced communications, synthetic biology, and advanced manufacturing R&D. The NSB applauds these efforts—it is wonderful to see the influx of national attention and both public and private sector investment in these areas, and NSF will continue to play a key role in addressing fundamental questions in these fields as we go forward.

It is worth noting that many of these research areas are ripe for an explosion of public and private investment in part *because* NSF supported early-stage research in these fields years ago. So in addition to furthering the development of research fields that are cutting-edge and now widely recognized as important, at its core, a central mission of NSF is to ask: what is the *next* big thing? NSF is the only agency that supports basic research in *and among* all areas of science. Identifying the most promising, creative ideas of America's research community, through rigorous peer review, is what will lead to the transformative discoveries that will shape our world decades from now. To continue our success, I advocate three things.

1—Continued robust Federal funding for basic research

First, the Nation needs robust, sustained Federal funding for research. The trends of other countries investing heavily in R&D are expected to continue as they recognize that such investments translate into economic growth and create jobs. Congress recognized this and responded in FY 2019; and we thank you also for the strong, bipartisan support shown for NSF in the initial FY 2020 Appropriations bills. But even with these increases, government spending on R&D is 0.7 percent of GDP, as compared to 1.69 percent in 1960. Since 2000, as worldwide investments in R&D have tripled, NSF's funding rate for grant proposals has fallen from 33 percent (total submitted proposals: 29,508) in 2000 to 21 percent (total submitted proposals 40,678) in 2017, leaving \$1.6 billion in great proposals unfunded.⁵ When that happens, the researcher may leave the country to pursue his/her work, submit the proposal elsewhere, perhaps to one of our international competitors, or the idea dies in the intellectual dustbin of unfulfilled promise, as the researcher drops the line of inquiry, or—worse—leaves S&E for another career. We need to maintain the trajectory on which your recent generous investments have placed NSF.

Funding without direction is akin to an airplane with no compass. As we seek to “be the best version of ourselves,” we need to formulate a strategy that considers everything from national needs to competitive advantages to technological opportunities. We need an enduring commitment to S&E leadership. An effective plan, built on a holistic evaluation of our national research portfolio, and a recognition that the best ideas come from researchers, would help us match our strategic priorities with

³National Science Board (2019). “Science & Engineering Labor Force,” *Science & Engineering Indicators 2020*. NSB–2019–8.

⁴National Science Board (2019). “Higher Education in Science & Engineering,” *Science & Engineering Indicators 2020*. NSB–2019–7.

⁵Report to the National Science Board on NSF's Merit Review Process, Fiscal Year 2017, NSB–2019–15.

our investments. If we are to continue to champion our “secret sauce” of free-wheeling creativity and entrepreneurial ethos, our vision of the future cannot be limited to competing with other countries in the current areas of global importance. To pursue the next “big thing,” our brightest minds will need the time, space, and resources to scout the path to new frontiers.

NSF has long sought a balanced portfolio, one that recognizes and embraces the knowledge that transformational discoveries often grow out of repeated “dead-ends” and small steps. Our portfolio balances large, long-term investments like LIGO with awards to individual investigators and small teams that can nimbly pursue innovative, out-of-the-box research. In recognition of the growing complexity and cost of some research, NSF’s portfolio also includes collaborations across disciplines, institutions, and research sectors, areas ripe for transformative discovery.

In anticipating what’s next for our national ecosystem, it is important to recognize the interdependent roles in our current one. A basic research agency like NSF has significant differences in scope and time horizons from private business and mission agencies. Partnerships among and between the Federal Government and universities, between universities and the private sector, and those with other non-profits have led to a system in which the Federal Government funds a majority of fundamental research, universities perform a majority of it, and industry funds and performs a majority of applied and developmental work. Public funding of curiosity-driven research is a sustained commitment over a long time horizon, and a competitive advantage for the United States. These investments set the table for directed research of the mission agencies and the private sector. Indeed, Figure 2 shows that the percentage of U.S. patents derived from government-funded research is near its all-time high.⁶

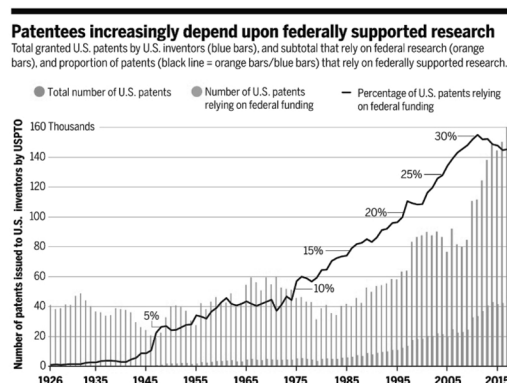


Figure 2: Increased dependence of U.S. patent on federal R&D

From: Fleming et al. (2019). “Government-funded research increasingly fuels innovation,” *Science*, 364(6446) 1139–1141.

2—Fostering America’s talent

More countries than ever are competing for the best minds, and these individuals have choices today that did not exist as recently as 20 years ago in selecting a place to study, perform research, and innovate. Industry and the Federal Government report that they are unable to find enough workers at all levels with enough STEM knowledge and skills. These reports are especially concerning in the national security arena, where employees must be U.S. citizens. For example, the National Security Agency has reported significant levels of attrition among personnel whose jobs require substantial STEM knowledge.⁷

Our ability to discover, invent, and innovate *relies* on our ability to train our own people while continuing to attract and retain the best and brightest from around the world. Recruiting the next generation will mean dispensing with outmoded stereotypes of scientists and engineers. As ideas live in people—not papers—this is a striking opportunity for our country. Our nation’s diversity of perspective and ex-

⁶Fleming et al., (2019). “Government-funded research increasingly fuels innovation,” *Science*, 364(6446) 1139–1141.

⁷Nakashima, Ellen & Gregg, Aaron. “NSA’s top talent is leaving because of low pay, slumping morale and unpopular reorganization.” *Washington Post*, Jan. 2, 2018.

perience can be a boon to creativity; our culture of risk-taking and entrepreneurship is an asset for turning discoveries into innovations; and our values of individual freedom—including the freedom to fail—openness and collaboration are natural accelerants of basic research.

The NSF Act directed the Foundation to “strengthen research and education in the sciences and engineering . . . throughout the United States, and to avoid undue concentration of such research and education.” The Board strongly agrees with this charge—no zip code or demographic should be unable to participate in the S&E economy, and we need *all* of our domestic talent if we want to compete in this era of globalized discovery. We must use the abilities and creativity of all our citizens. To do so, we must do more to diversify our STEM-capable workforce, particularly as, according to the Census Bureau, by 2042 our country will be a majority-minority nation.

NSB believes that for our Nation to continue to thrive and lead in the industries of the future we can no longer rely on a relatively small and distinct “STEM workforce.” Congress, the Administration, business leaders, educators, and other decision-makers must work together to ensure that Americans have the STEM knowledge and skills to thrive, leveraging the hard work, creativity, and ingenuity of women and men of all ages, education levels, and backgrounds.⁸ We must improve STEM education here in the U.S. by giving everyone the opportunity for hands-on learning starting at an early age, for example. We need to remember that education is a public good, and that public universities and colleges have a special role to play in providing access to high quality STEM education to students in every state. We must provide our citizens with the problem-solving skills needed for the lifelong learning that is now required to adapt and thrive in a rapidly changing job market, one often driven by advances in S&E. We need scientists in every region of the country searching for cures, engineers building stronger bridges, factory workers making our cars safer, technicians keeping our labs and hospitals operating, and farmers producing healthier crops using fewer resources.

Even as we work to build our domestic STEM-capable workforce at all levels, including the skilled technical workforce, there is another component to maintaining our preeminence in S&E. It is critical that we continue, through clear and consistent policies, to welcome curious, creative, and ambitious researchers from overseas. This does not mean being naïve—other nations are actively courting this globally mobile talent, sometimes aggressively enough to violate U.S. government policies. Rather it means welcoming those who embrace our values.

3—Embracing and promulgating our values

In the belief that the pursuit of knowledge is a universal global enterprise, best undertaken through an open exchange of ideas and sharing of outcomes, with limited national security exceptions, the U.S. must avoid the temptation to engage in a head-to-head competition with those who choose to conduct their fundamental science and engineering enterprise with less transparency. Instead, the U.S. should reaffirm its unambiguous commitment to the highest ethical and technical conduct of its research, leading the way in open worldwide collaborations, open publication, and archiving data for public use. The U.S. should work with those who share our values, remaining confident in its conviction that behavior as a model citizen in the science and engineering community will serve as an example for others to emulate, as well as maintaining the U.S. as the destination of choice for the world’s best minds. Through principled leadership in the exercise of science and engineering research, the U.S. will retain its seat at the table of like-minded nations. The partnerships and research collaborations that flourish in an environment of shared values will provide an incubator for an unlimited variety of scientific and engineering discoveries. These discoveries, in turn, could generate new innovative solutions to global problems and/or reveal heretofore unknown secrets about our universe.

This is not a naïve vision of utopia. There are sensitive areas of research in which national security considerations must prevail. National security and economic espionage conducted or supported by foreign entities must be vigorously challenged. U.S. universities and colleges must help promote scientific openness and integrity and safeguard information that impacts national security and economic competitiveness, including rigorously adhering to conflict of interest and conflict of commitment policies. But, as stated in President Reagan’s NSDD-189, “The strength of American science requires a research environment conducive to creativity, an environment in which the free exchange of ideas is a vital component.” National Security Advisor Condoleezza Rice reiterated this U.S. commitment in 2001, stating, “The key to

⁸National Science Board (2018). “Our Nation’s Future Competitiveness Relies on Building a STEM-Capable U.S. Workforce,” NSB-2018-7.

maintaining U.S. technological preeminence is to encourage open and collaborative basic research. The linkage between the free exchange of ideas and scientific innovation, prosperity, and U.S. national security is undeniable.” Consistent with these pronouncements, distinctions must be made between the truly critical secrets and the inconvenient losses that can occur in an open society. If the U.S. continues to conduct its S&E enterprise consistent with the principled traditions that have yielded the success of the past 75 years, the benefits it realizes from nurturing a global community of similarly principled partners will far outweigh the losses it may suffer as a result of the openness it champions.

Conclusion

Fifty-nine years ago, President John F. Kennedy set America on a path to the Moon. In 2019, as we celebrate the 50th anniversary of humanity’s first steps on that new world, we find ourselves once again in “an hour of change and challenge.” Competition and excitement arise from science and technological advances everywhere, in every field, in research and industry and academia and business, and from many other nations, who are seeing their chance to rise. Healthy competition provides benefits to all of humanity—science, and particularly fundamental research conducted in a transparent and open fashion, is not a zero-sum game. New knowledge benefits everyone. If the U.S. wants to invent the future, then we must up our own game, emphasizing freedom, individuality, creativity, and risk-taking, building on a foundation of community that is diffuse and networked, open and transparent.

Our national commitment to winning the race to the Moon, and our belief that we could do anything we put our minds to, spurred creative collaboration and competition that resulted in scientific and technological advances that have benefited every one of us, far beyond the original goal. Today, let us be inspired to once again dream boldly and take risks in the pursuit of fundamental knowledge and innovation. Maintaining our global leadership will require increased efforts from government and industry, working in partnership with our world-leading public and private universities. Together, we can pursue grand visions, enable revolutionary ideas, and see what unexpected advances may emerge from asking fundamental scientific questions.

As I conclude, I return to the story of Dr. Whittingham, now at the State University of New York, where his continuing work to improve battery technology has been supported by NSF for over 30 years. He discovered a fundamental chemical property of specific solid materials, and *then* saw the potential applications of his discovery—taking him down a new, unexpected path that led to an invention that changed our world. Stories like this are why we need to attract and fund the best *people*, as well as the best ideas. For the U.S. to maintain preeminence in S&E, for us to invent the future, we need to develop and attract the best minds. Then we must give them the time and space—and resources—to explore, to not be sure exactly what they might find, or why it might be useful; but being sure in the knowledge that discovery will ultimately reap huge, unexpected benefits for humanity. We know this because we have seen this story of unleashed creativity play out, over and over again. It is what has brought us the technology-driven world we live in today—and it is what will bring us the innovations that will shape our tomorrows.

If we are bold. If we are fearless. If we are true to our heritage as a nation of people who were not circumscribed by the boundaries of others, but who instead looked over the horizon and asked: What’s out there? *What’s next?*

Senator GARDNER. Thank you, Dr. Souvaine.
Dr. Shaw?

STATEMENT OF DR. DAVID SHAW, PROVOST AND EXECUTIVE VICE PRESIDENT, MISSISSIPPI STATE UNIVERSITY

Dr. SHAW. Chairman Wicker, Chairman Gardner, Ranking Member Baldwin, and Members of the Committee, thank you for the opportunity to testify before you today.

I’m here to share with you examples of the impact that universities can have on American economic and strategic leadership and at the same time encourage further investment in the research and innovation that is uniquely American.

Mississippi State University has long played a leadership role in our state's economic development and has embraced that role as a means to lift us up.

Federal research investment has made a tremendous difference in our state. MSU won a National Science Foundation Engineering Research Center in 1990 focused on computational field simulation. We have many success stories that came from that ERC but none more important than how it was used to attract Nissan to the state of Mississippi.

We leverage the ERC to create a new Center for Advanced Vehicular Systems with a combination of basic research and industrial outreach to support the automotive industry in the state. In the past 10 years, CAVS has an impact of over \$2.9 billion in the state through jobs saved or created. Without that NSF investment, none of this would have been possible.

Universities are also engines of entrepreneurship. At MSU, our Thad Cochran Research, Technology, and Economic Development Park is full to overflowing and an additional incubator has been purchased in downtown Starkville. We are proud to partner with leading technology companies, such as II-VI, Incorporated, Camgian Microsystems, HBM nCode, and Babel Street, and we have also developed companies from student and faculty entrepreneurs, such as Horne Cyber.

Universities conduct research and development activities that enable civil applications of basic and defense-related research. MSU is the lead institution of the FAA Center of Excellence for unmanned aircraft systems, called ASSURE. It has been tasked with conducting research addressing FAA's highest priorities and has become the de facto standard for answering the most pressing questions regarding safe and effective use of drone technologies in civil applications.

We've also partnered with NOAA to build the fourth fastest computer in U.S. academia focused on providing the tools necessary for advancing research in weather and severe storm simulation.

We're also partnering with other agencies, such as USDA and Homeland Security, to meet their computational needs, as well.

As a land grant, MSU is consistently recognized as a leading research institution in agriculture and natural resources. We have many success stories from the partnership that we have with USDA's Agricultural Research Service, but none more important than the Warm Water Aquaculture Program that has spawned a strong industry in the U.S. and provides safe, flavorful, and healthful products to the U.S. and international consumers.

I provided examples relevant to my university, but I could tell similar stories from many other institutions. However, these success stories are in jeopardy without renewed investment from the Federal Government.

To quote from the National Academy of Sciences' 2010 Study *Rising Above the Gathering Storm Revisited*, "Today, for the first time in history, only a minority of American adults believe that the standard of living of their children will be higher than what they themselves have enjoyed. To reverse this foreboding outlook will require a sustained commitment by both individual citizens and by the Nation's government at all levels."

Members of the Committee, I urge you to seek Federal investment of research funding in just those terms: investment. These investments are critical if we are to ensure our future as an economic and strategic global leader and this investment must be, first, broad-based geographically. We must support the best and brightest students and researchers wherever they are.

Second, must be trans-disciplinary in nature. The most challenging issues that we face today cannot be solved by anyone or even a few disciplines.

Third, it must be broadly supportive of both fundamental and developmental research endeavors, and, finally, it must encourage Federal, state, university, and industry partnerships. We must find ways to invest in research that leads directly to innovation that spawns entrepreneurship and economic development in the private sector.

Chairman Gardner, Ranking Member Baldwin, Chairman Wicker, Members of the Committee, I thank you again for the opportunity to testify before you today. Should there be any need for follow up conversations, I and Mississippi State University stand ready to serve.

Thank you.

[The prepared statement of Dr. Shaw follows:]

PREPARED STATEMENT OF DR. DAVID SHAW, PROVOST AND EXECUTIVE VICE
PRESIDENT, MISSISSIPPI STATE UNIVERSITY

Chairman Gardner, Ranking Member Baldwin, and members of the committee, thank you for the opportunity to testify before you today.

I am here to share with you today several examples of the impact that universities can have on American economic and strategic leadership, and at the same time encourage further investment in the research and innovation that is uniquely American. The university system in the U.S. has been the envy of the world, and nowhere can a public, land-grant university have a bigger impact than on a state like Mississippi, where pressing needs can be changed to immense opportunity. Mississippi State University has long played a leadership role in our state's economic development, and has embraced that role as a means to lift us out of poverty and disadvantage. First and foremost, we believe that this impact comes from a high-quality education of our citizens, coupled with a strong work ethic, integrity, and passion for improvement.

Federal investment in research has made a tremendous difference in our state. Mississippi State University (MSU) won a National Science Foundation (NSF) Engineering Research Center (ERC) in 1990, focused on computational field simulation. We have many success stories that came from that ERC, but none more important than how it was used to attract Nissan to the State of Mississippi. As a part of the incentive to attract Nissan, we leveraged the ERC to create a new Center for Advanced Vehicular Systems (CAVS) at MSU, with a combination of basic engineering research and industrial outreach to support the automotive industry in the state. In the past ten years, CAVS has had an impact of over \$2.9 billion in the state through jobs saved or created, as measured by the U.S. Commerce Department. Without the NSF investment, I doubt any of this would have been possible.

Universities are also engines of entrepreneurship. At MSU, our Thad Cochran Research, Technology and Economic Development Park is full to overflowing in phase 1, with phase 2 now being filled, and an additional incubator purchased in downtown Starkville. We are proud to partner with leading technology companies such as II-IV, Inc., Camgian Microsystems, HBM nCode, and Babel Street. However, we have also developed companies from student and faculty entrepreneurs. Horne Cyber is just such a company; founded based on technological capabilities of faculty, it is now one of the leading cyber-security companies in the U.S.

Land-grant universities are heavily invested in community success as well. Our Carl Small Town Center has taken a nationally-recognized leadership role in helping smaller cities reimagine their future and develop a strategic plan to turn failing communities into thriving cities and towns. The MSU Gulf Coast Community De-

sign Studio was created after Hurricane Katrina, and has won national awards for its design work for resilient and cost-effective housing after natural disasters.

Universities conduct research and development activities that enable civil applications of basic and defense-related research. MSU is the lead institution of 23 universities that formed the Federal Aviation Administration (FAA) Center of Excellence for unmanned aircraft integration into the national air space. The Center of Excellence for Unmanned Aircraft Systems Alliance for System Safety of UAS through Research Excellence (ASSURE) has been tasked with conducting research addressing FAA's highest priorities, including air-to-ground collision modeling, detect-and-avoid technologies, control and communications, and human factor performance in operations. The ASSURE consortium has become the de facto standard for answering the most pressing questions regarding safe and effective use of drone technologies in civil applications. Since its founding in 1948, our Raspet Flight Research Lab has been a premier center of excellence for innovation. Raspet served as an incubator for Stark Aerospace, Airbus Helicopter, Honda Jet, GE Aviation, and Aurora Flight Sciences.

Following graduation from the ERC program, which I mentioned earlier, MSU recognized the unique opportunity it had created, and heavily invested in high performance computing as a tool for modeling and simulation that would not be possible otherwise. As a result, we have partnered with the National Oceanic and Atmospheric Administration (NOAA) to build the fourth-fastest computer in U.S. academia, focused on providing the tools necessary for advancing research in weather and severe storm simulation. We are also partnering with other agencies such as the U.S. Department of Agriculture (USDA) and Homeland Security to meet their computational needs. This computing capability is also extended to corporate partners as well, moving their capabilities into a parallel-computing environment through our expertise.

As a land-grant, MSU is consistently recognized as a leading research institution in agriculture and natural resources. We have many, many success stories from the partnership we have with USDA's Agricultural Research Service, but none more important than the warmwater aquaculture program that has spawned a strong industry in the U.S. that provides safe, flavorful, and healthful products to the U.S. and international consumers.

I could continue with many other research and development successes that have come from my institution; however, these are sufficient to make the point—none of them would have happened without Federal investment of research dollars. Research funded by Defense, NOAA, FAA, USDA, Commerce, Interior, Homeland Security, and many other agencies has all stimulated innovative research findings that are leading change in our state and nation.

I have provided examples relevant to my university, but I could also tell similar stories for many other institutions across the Nation. However, these success stories are in jeopardy without renewed investment from the Federal government. To quote from the National Academies of Science 2010 study "Rising Above the Gathering Storm, Revisited": "Today, for the first time in history, America's younger generation is less well-educated than its parents. For the first time in the Nation's history, the health of the younger generation has the potential to be inferior to that of its parents. And only a minority of American adults believes that the standard of living of their children will be higher than what they themselves have enjoyed. To reverse this foreboding outlook will require a sustained commitment by both individual citizens and by the Nation's government . . . at all levels."

Members of the committee, I urge you to see Federal investment of research funding in just those terms: investment. These investments are critical if we are to ensure our future as an economic and strategic global leader. And, this investment must be:

1. Broad-based geographically. We must support the best and brightest students and researchers wherever they are, not just at a few locations if we as a nation are to make the progress you envision.
2. Trans-disciplinary in nature. The most challenging issues we face today cannot be solved by any one or even a few disciplines. Rather, issues such as health disparity, food security, and water scarcity can only be solved by the hard sciences and social sciences working together in new and novel ways.
3. Broadly supportive of both fundamental and developmental research endeavors. Both basic and applied research are critical if we are to lead the world in innovation and entrepreneurship.
4. Encouraging federal, state, university and industry partnerships. We must find ways to invest in research that leads directly to innovation that spawns entrepreneurship and economic development in the private sector. Historically, our

economy is based on this innovation, and with reduced private investment in research, Federal funding is ever more important if we are to continue to lead the world.

Chairman Gardner, Ranking Member Baldwin, members of the committee, I thank you again for the opportunity to testify before you today. Should there be any need for follow-up conversations, I and Mississippi State University stand ready to serve.

Senator GARDNER. Thank you, Dr. Shaw.
Dr. Panchanathan.

**STATEMENT OF SETHURAMAN (PANCH) PANCHANATHAN, PhD,
EXECUTIVE VICE PRESIDENT AND CHIEF RESEARCH
AND INNOVATION OFFICER, ARIZONA STATE UNIVERSITY**

Dr. PANCHANATHAN. Thank you, Chairman Wicker, Chairman Gardner, Ranking Member Baldwin, and Senator Peters for this opportunity.

First of all, I would be remiss if I didn't thank Senator Sinema for the wonderful kind introduction and her friendship. We are proud of her, as our phenomenal Senator from the great state of Arizona, as well as her fellow Senator.

It is a privilege to have the opportunity to discuss how to use innovation as a means for advancing our Nation's competitiveness into the future. I thank you for holding the hearing on this very important topic today.

Our nation has entered a new bold frontier in science and technology. At no other time in our history have advancements been accelerating at the scale and the scope that we're seeing today.

Our country has always been in the vanguard because of the innovative spirit that permeates everything that we do. We are not only in a competition to be ahead of other countries, but in a race to outperform ourselves. This is the ticket to ensuring economic competitiveness and strategic leadership.

I would like to talk about four elements that I believe are important for economic competitiveness. Number 1, a strong research and development ecosystem. My colleagues have written on this, too. We are a global leader because of the strong Federal investments in science, technology, engineering, higher education, and workforce development.

I'm enthusiastic about American leadership in the industries of the future, especially in the areas of AI, data science, 5G, advanced manufacturing, synthetic biology, and quantum science.

As a member of the National Science Board, I'm proud of the National Science Foundation's efforts, such as the Big 10 ideas, which will contribute significantly to enhancing our global competitiveness.

It is imperative that there is increasing focus on stimulating and seeding bold, large-scale foundational research with meaningful vital impact.

Number 2, a strong learner ecosystem. A wider element of advancing U.S. competitiveness involves preparing all citizens for the future. Automation is changing the ways we learn, live, and work. Some jobs will be augmented, new roles will be born, and some positions may disappear.

Therefore, citizens must become master learners with the capability to adjust and adapt throughout their life. In order to prepare our learners for the future of work, we should not only provide them with skill sets, but also endow them with mindsets for success. It is imperative that quality education and training opportunities, up-skilling and re-skilling of talent, are accessible to all, regardless of their socioeconomic background, geographic location, or where they are in their career or educational trajectory.

Thanks to the proliferation of technology, we cannot only train the skilled technical workforce, but also virtually connect this talent to exciting job opportunities.

Number 3, a strong partnership ecosystem. Partnerships and collaborations with and among regions are key to furthering our competitiveness, leadership positions, and prosperity.

This necessitates developing synergistic alliances between academia, corporates, government, and nonprofit organizations. We should incentivize building corporate research laboratories that seamlessly span academic and industry to get the best-trained workforce, as well as the fastest technology transfer outcomes.

It is important to catalyze such partnerships at scale to ensure prosperity across both urban and rural areas of our Nation.

Number 4, a strong economic development ecosystem. To create a robust economic development ecosystem, it is critical that we rapidly translate basic scientific research to the marketplace. This is achieved through bold translational research, corporate partnership with seamless technology transfer processes, and incubating business ventures.

The recent NIST Green Paper, *Unleashing American Innovation*, has put forth options for enhancing technology transfer outcomes. At ASU, we have many programs that serve as portals for unleashing the innovative spirit in our community.

For example, the Venture Vets Program taps into the immense entrepreneurial potential that is resident in our military population to launch their ideas into successful ventures.

We need such programs replicated in all regions across the Nation. I am confident that if we can address some of these priorities, we will continue to be in the vanguard of global competitiveness and economic prosperity.

Thank you for the opportunity to contribute to this timely and important discussion. I look forward to answering any questions you may have.

[The prepared statement of Dr. Panchanathan follows:]

PREPARED STATEMENT OF SETHURAMAN (PANCH) PANCHANATHAN, PH.D., EXECUTIVE VICE PRESIDENT AND CHIEF RESEARCH AND INNOVATION OFFICER, ARIZONA STATE UNIVERSITY

ASU Charter:

ASU is a comprehensive public research university, measured not by whom it excludes, but by whom it includes and how they succeed; advancing research and discovery of public value; and assuming fundamental responsibility for the economic, social, cultural and overall health of the communities it serves.

Our nation has entered a new, bold frontier in science and technology. At no other time in our history have advancements in science and technology been accelerating at the scale and scope we are seeing today. This will undoubtedly continue into the future. Our country has always been in the vanguard because of the innovative spirit

that permeates everything that we do. We are looked upon as a model to be emulated by countries across the globe.

I would like to emphasize that innovation is not only a skill set, but more importantly, a mindset. We therefore need to do everything possible to cultivate, nurture, and advance this innovative spirit to ensure America's competitiveness and strategic leadership. We are not only in a competition to be ahead of other countries, but also in a race to outperform ourselves. This is the ticket to ensuring our economic competitiveness and well-being. How we, as a country, act and advance our science and technology aspirations will have a direct impact on our economic and national security. I am pleased and grateful that we are having this discussion today.

I would like to now outline some of the ways in which we can continue to be in the forefront.

Strong Research and Development Ecosystem

We are a global leader because of the strong Federal investments over several decades in science, technology, engineering, higher education, and workforce development. Over the last four decades, total U.S. R&D investment as a proportion of the GDP has remained around 2.5 percent with Federal R&D at 11–13 percent of discretionary spending¹. A strong research environment in academia and industry supported by a robust investment strategy will guarantee a vibrant innovation economy for our Nation.

While it is imperative to have a robust foundation of basic science and technology research, we should also augment this with focused efforts in thematic areas that position our Nation as a global leader in emerging and critical areas. I am enthusiastic about American leadership in the Industries of the Future in the areas such as AI, data science, 5G, advanced manufacturing, synthetic biology, and quantum science².

A strong R&D ecosystem with Federal labs, academia, and industry focused on advancing new ideas can be a powerful recipe for economic development. For example, the multitude of research laboratories in Colorado have been an impetus for significant economic progress, primarily because of the ideas generated from basic research being translated into solutions³. At Arizona State University, we are focused on advancing fundamental science and discovery at scale, and working seamlessly across disciplines to address global grand challenges. Our researchers have pioneered solutions to pandemics such as Ebola and Zika⁴, addressed new energy futures with an industry consortium by designing low cost solar photovoltaics⁵, and deployed flexible displays for situational awareness critical to ensuring the safety of our warfighters⁶.

As a member of the National Science Board, I am proud of the National Science Foundation's efforts such as *Big 10 Ideas*⁷ which will contribute significantly to enhancing our global competitiveness. It is imperative that we increasingly focus on stimulating and seeding bold, large-scale foundational research with meaningful societal impact.

Our competitors are increasing their investments at a much greater pace than before¹. Global R&D investment has increased by 100 percent since 2000 with U.S. investment increasing by 40 percent. We are now 10th in research intensity (R&D as a proportion of GDP) behind countries such as Germany, South Korea, Singapore, and China¹—this comes as a result of economic growth strategies set by those countries. There is an impending need for continuing strong investments in research and development to expand basic science and engineering research as well in focused areas of national importance in order to strengthen our economic competitiveness.

Strong Learner Ecosystem

"Intellectual growth should commence at birth and cease only at death."

—Albert Einstein

Global competitiveness demands a strong focus on science, technology, engineering, and math. It requires a workforce comprised of lifelong learners capable of

¹American Association for the Advancement of Science. *Federal R&D Budget Trends: A Short Summary*. 2019.

²White House. *America Will Dominate the Industries of the Future*. 2019.

³Colorado Office of Economic Development and International Trade. *Economic Development Commission*. 2019.

⁴Arizona State University. *Origins of World's First Cure for Ebola had Roots at ASU*. 2019.

⁵National Science Foundation. *New Research Center to Make High-Efficiency Solar Energy Technologies Sustainable, Ubiquitous, and Cost-Effective*. 2011.

⁶Arizona State University. *ASU Center Produces New Largest Color Flex Display*. 2013.

⁷National Science Foundation. *NSF's 10 Big Ideas*. 2019.

thinking critically, pivoting when necessary, and successfully adapting to our ever-changing science and technology landscape. A vital element of advancing U.S. competitiveness involves preparing *all* citizens for the fourth industrial revolution and into the future. Automation is changing the ways we learn, live, and work. Some jobs will be augmented, new roles will be born, and some positions may dissipate. Citizens must become master learners with the capability to adjust and adapt throughout their life.

In order to prepare our learners for the future of work, we should not only provide them with skill sets, but also endow them with mindsets for success. Important components of these mindsets include creative thinking, problem solving, working across disciplines, and an entrepreneurial approach. These qualities are best imbibed by students when the institutions of learning exemplify them.

It is imperative that quality education and training opportunities, and upskilling and reskilling of talent are accessible to all, regardless of their socioeconomic background, geographic location, or where they are in their career and educational trajectory. Empowering online learning platforms like MIT edX⁸ and ASU EdPlus⁹ offer quality higher education accessible to all. These universal learning models help reshape society by democratizing access to learning. While innovation leading to start-ups is a great beginning, we need to be able grow these enterprises domestically. This requires a spectrum of talent that is available at scale. Thanks to the proliferation of technology, we can not only train the skilled technical workforce but also virtually connect this talent to meet the demands of these enterprises. More importantly, this ensures prosperity across the Nation.

Strong Partnership Ecosystem

Partnerships and collaborations within and among regions are key to furthering our competitiveness, leadership position, and prosperity. This necessitates developing synergistic alliances between academia, corporates, government, and non-profit organizations. The recent inter-agency efforts around AI is an excellent example of how agencies can work together to mutually leverage investments to position us into the future¹⁰.

Of the \$542B of the U.S. R&D expenditures in 2017, 73 percent was by the business sector, and 13 percent by universities and colleges¹¹. Programs that promote strong partnerships between academia and industry can take full advantage of the collective investments by Federal agencies, states, and corporates. Companies need this rich, symbiotic relationship with universities to generate new ideas and train the highly talented workforce that is necessary for them to be successful. The recent White House Industries of the Future initiative calls for leveraging the strength of our unique R&D ecosystem consisting of the Federal government, private industry, colleges and universities, research institutions, and science philanthropies².

For example, Clemson University's International Center for Automotive Research (CU-ICAR)¹² involves several partners for advancing research, development, and translation that has led to high-value job creation in the sustainable automotive industry. The variety of partnership models enables industry and community partners to customize their relationships to derive the maximal value. ASU has cultivated strong partnerships with corporates locally, nationally, and globally. For example, ASU and Starbucks partner on the College Achievement Plan¹³, which provides educational opportunities for Starbucks employees, a model program of an academic-corporate partnership towards building a strong workforce. We have more than 13,000 students enrolled in this program with 3,000 graduates already over the past 5 years. These are exemplars of how such partnerships create real impact at the individual, community, and macroeconomic level. Similarly, as the Advisor for Science & Technology to the Governor of Arizona, my role is to work diligently to connect industry and academia around thematic areas, with the goal of creating a statewide innovation ecosystem that propels us into the future.

We should incentivize building corporate research laboratories that seamlessly span academia and industry to get the best trained workforce, as well as the fastest technology transfer outcomes. It is important to catalyze partnerships at scale to ensure prosperity across both urban and rural areas of our Nation.

⁸Massachusetts Institute of Technology edX. 2019.

⁹Arizona State University. *EdPlus at ASU Partners to Provide Universal Learning Techniques to Youth*. 2019.

¹⁰White House. *Artificial Intelligence for the American People*. 2019.

¹¹National Science Foundation. *U.S. R&D Increased by \$22 Billion in 2016, to \$515 Billion; Estimates for 2017 Indicate a Rise to \$542 Billion*. 2019.

¹²Clemson University International Center for Automotive Research. 2019.

¹³Arizona State University. *More than Tuition: Trailblazing Starbucks College Achievement Plan Continues to Offer Partners Support, Flexibility with ASU Online*. 2019.

Strong Economic Development Ecosystem

To create a robust economic development ecosystem, it is critical that we rapidly translate the basic scientific research to the marketplace. This is achieved through bold translational research, corporate partnerships with seamless technology transfer processes, and incubating business ventures, all enabled through interagency and regional cooperation.

Partnership frameworks that accelerate the continuum from basic research to translational research to licensing/startups to impact, will increasingly become a driving force. We need to ensure ease and speed of translation through streamlined IP policies and new models for agreements for commercializing technology. As a recent participant on the advisory council for the green paper focused on “*Unleashing American Innovation*” by the National Institute for Standards and Technology (NIST), I was gratified to see the options put forth for enhancing technology transfer including streamlining Federal regulations, enabling greater flexibility for public-private partnerships, increasing engagement with private-sector investors, building a more entrepreneurial workforce, and improving support for innovation¹⁴.

At ASU, we have evolved a three-pronged strategy: working with the state and cities to help expand the footprint of existing companies, attracting new companies from outside Arizona (and the U.S.), and incubating new ventures to rapidly vitalize the Arizona economic development ecosystem and the state’s competitiveness. We find decision-makers have often cited the strong partnership between ASU and the regional entities as the critical factor in their decision to expand or relocate to Arizona¹⁵.

We also work in partnership with the cities in Arizona using the platform of innovation campuses. For example, ASU’s Skysong Innovation campus, in partnership with the City of Scottsdale, houses small and medium enterprises from across the globe, as well as entrepreneurial ventures led by our students, faculty, and the community. This co-working environment fully leverages all assets and creates a synergy that benefits all. It is anticipated to have over \$30B of economic impact over 30 years¹⁶. We also have many programs that serve as portals for unleashing the entrepreneurial spirit in our community. For example, our Venture Vets program taps into the immense entrepreneurial potential that is resident in our active, reserve, and veteran personnel, as well as in active duty military spouses, to launch their innovative ideas into successful ventures¹⁷.

It is imperative that we leverage the broad demographic of talent that exists across the Nation. While we have such models primarily concentrated in highly populated areas, we need to ensure that these are replicated in all regions across the country. A vibrant economic development ecosystem ensues when there is a strong partnership between the federal, state, and local entities co-investing in innovation, industries of the future, education and workforce development, and start-up ventures.

I am confident that if we can address and continue to deploy these priorities, we will continue to be in the vanguard of global competitiveness and economic prosperity.

Thank you for the opportunity to contribute to this timely and important discussion. I will be pleased to answer any questions you may have.

Senator BALDWIN. Thank you.

Dr. Blank.

STATEMENT OF REBECCA M. BLANK, CHANCELLOR, UNIVERSITY OF WISCONSIN-MADISON

Dr. BLANK. Chairman Wicker, Ranking Member Baldwin, thank you very much for inviting me to be part of this hearing.

I am proud to lead one of the top research universities in the world. The University of Wisconsin in Madison is ranked sixth in the Nation in terms of research expenditures and funding from the

¹⁴ NIST. *NIST Releases Findings on Increasing the Innovation Impacts of Federally Funded R&D*. 2019.

¹⁵ Arizona State University. *ASU, Infosys Partnership will Accelerate Workforce Development in Arizona*. 2019.

¹⁶ Skysong. *SkySong Projected to Make Major Economic Impact on Scottsdale and Valley of the Sun Over the Next 30 Years*. 2016.

¹⁷ Arizona State University. *Operation Start-up: ASU Launches Veteran Accelerator for Aspiring Entrepreneurs*. 2015.

Federal Government supports about 2,000 awards at my institution every year.

My message to you today is twofold. First, U.S. global leadership in science, technology, and innovation is threatened as other countries rapidly increase their investments in these areas.

Second, this is not inevitable. We can take steps to maintain our long-term leadership in innovation and discovery.

A strong and sustained commitment to Federal investments in scientific research will drive the U.S. economy forward and lead to improvements in the human condition.

Let me start with the first point. U.S. global leadership in science, technology, and innovation is threatened.

The U.S. is one of the few countries in the OECD whose public investments in R&D have declined in the past 25 years. South Korea and Germany have surpassed the U.S. in the share of GDP going into publicly funded research. Most notably, China's investment in R&D has risen rapidly and is expected to surpass the U.S. in the next few years.

Furthermore, declines in research dollars go along with declines in U.S. published research articles and in patents. The U.S. now trails both the EU and China in producing Bachelor's degrees in science and engineering. We're also behind the EU and will soon trail China in the number of science Ph.Ds.

Today's basic science research is the foundation on which future advances in technology, health, and productivity are built. Countries that are expanding their R&D investments will reap the benefits for decades to come. The U.S., with reduced investments in science, will no longer be the future leader of innovation.

My second major point is this relative decline in U.S. research leadership is not inevitable. If we don't want to lose ground, research funding increases should at least match inflation, but if we want to catch up with our competitors, funding must grow even faster.

While NIH has seen funding increases, it is important that other key research agencies, such as the National Science Foundation, not get left behind. Too many researchers are vying for limited resources which is particularly challenging for new and mid-career investigators.

The American Innovation and Competitiveness Act, the 21st Century Cures Act, and the Next Generation Researchers Act are all moving us in the right direction, and I want to thank those of you who have led in sponsoring this legislation, including Senators Baldwin, Gardner, and Peters.

The research funded today leads to life-saving discoveries in the future and also helps to drive the U.S. economy as cutting edge scientific research is translated into real-world activities, sometimes sparking entirely new industries.

Here's one example. Last year, a group from UW—Madison started the Forward Bio Institute. It focuses on bio-manufacturing. One project involves manufacturing 3-D human brain tissue that contains tumors as a way to test drug therapies.

UW—Madison discoveries have already created more than 350 startup companies and added 2.3 billion to the Wisconsin economy.

But the impact of investments in research is more than just economic. Research improves our lives and our health. One of the most salient examples comes from the war on cancer.

In 2009, six economists published a large study that looked at cancer outcomes between 1988 and 2000. They found the likelihood of surviving cancer of any kind improved markedly between these years and this was closely linked to scientific advances in research and treatment.

In fact, better treatments developed through scientific research gave cancer patients in the U.S. 23 million additional years of life in just that 12-year period.

If the U.S. wants to maintain its innovative edge, create meaningful jobs, realize economic growth, and improve our quality of life, we must make funding for basic science a national priority.

I encourage Congress to renew the partnership between the Federal Government and research universities. This means stable and predictable research funding to build labs, experiment with new ideas, and complete long-term research projects.

It means training the next generation of scientists by supporting trainees with individual fellowships and institutional grants. It means prioritizing science in the Federal budget. It means a strategic plan to promote U.S. science.

With this type of investment, the U.S. will maintain its position as the global leader in research.

Thank you.

[The prepared statement of Dr. Blank follows:]

PREPARED STATEMENT OF REBECCA M. BLANK, CHANCELLOR,
UNIVERSITY OF WISCONSIN—MADISON

Chairman Gardner, Ranking Member Baldwin, and members of the Subcommittee, thank you for inviting me to discuss international competitiveness and the importance of Federal investments in research. Much of our Nation's Federal research funding goes to America's leading research universities, including the University of Wisconsin—Madison, where I serve as Chancellor. UW—Madison is ranked six in the Nation for overall research expenditures annually, and funding from the Federal government supports about 2,000 awards at my institution each year.

My message to you today is two-fold: First, U.S. global leadership in science, technology and innovation is threatened, as other countries rapidly increase their investments in research and grow their STEM workforce.

Second, this is not inevitable; we can take steps to maintain our long-term leadership in innovation and discovery. With a strong and sustained commitment to Federal investment in scientific research we can continue to be a world leader. Such investments will drive the U.S. economy forward and lead to improvements in the human condition.

Let me start with the first point: U.S. global leadership in science, technology, and innovation is threatened.

The U.S. is one of the few Organisation for Economic Co-operation and Development (OECD) countries whose public investments in research and development have declined in the past 25 years. Countries that are highly competitive with the U.S., such as South Korea and Germany, have been investing more and more public funds in R&D and have surpassed the U.S. in the share of GDP going into publicly-funded research.

Most notably, China's investment in R&D has risen rapidly and is expected to surpass the U.S. in the next few years.

That country's Made in China 2025 initiative outlines the intent to become an international leader in frontier sectors such as advanced robotics, aerospace, and biotechnology. Meanwhile, the U.S. Government's investment in research and development (R&D) is roughly half what it was in the mid-1970s as a percent of GDP, according to American Association for the Advancement of Science data estimates.

In recent years, Congress has started to close the gap, but greater investment is still needed. The increases Congress has provided agencies such as the National Institutes of Health (NIH) over the last four years are helping to correct the devastating effects of sequestration and budgets that declined in inflation-adjusted dollars.

However, while NIH has seen funding increases, it is important that other key research agencies such as the National Science Foundation (NSF) see similar increases and not get left behind. We know that too many researchers are vying for limited resources, creating a hypercompetitive environment that is particularly challenging for new-and mid-career investigators. Many highly meritorious research proposal applications go unfunded. In financial year 2016, the NIH received 26,187 applications for new R01 grants. Only 17.3 percent were funded.

As specified in the 21st Century Cures Act, NIH continues to pursue a number of important initiatives, including the Cancer Moonshot, the All of Us program (formerly the Precision Medicine Initiative), and the Brain Research through Advancing Innovative Neurotechnologies (BRAIN) Initiative.

These programs focus resources on specific areas of human health that are critical for further discovery-oriented research. But they build upon decades of more basic biological research that created the scientific knowledge necessary for more targeted, disease-focused efforts to succeed. To advance our knowledge and lay the groundwork for similar opportunities in the future, the U.S. must continue to invest in basic as well as translational research, and to incentivize creative investigator-initiated inquiry.

Chinese R&D investment has grown remarkably over the past two decades according to NSF data. Among all countries, China is now number two in expenditures on R&D, and accounts for 20 percent of total world R&D expenditure. Its rate of R&D investment growth greatly exceeds that of the U.S. and the E.U.

Unfortunately, the U.S. is not just failing to keep pace with other countries in terms of research dollars. According to the 2019 benchmark report from the Task Force on American Innovation (TFAI)—an alliance of leading American companies and business associations, research university associations, and scientific societies—while U.S. researchers will produce more published articles than other countries, that output is declining and China is catching up. China ranks just behind the U.S. in terms of annual research publications, particularly in fields such as computer sciences and engineering, highlighting the country's research priorities.

The report also highlights declines in the U.S.'s patent productivity in recent years, while East Asian economies such as South Korea, Taiwan, and Singapore have accelerated their patent output.

Other nations also outperform the U.S. in science and engineering education.

The TFAI report notes that the U.S. trails the E.U. and China in output of bachelor's degrees in science and engineering. China is now the world's number one producer of undergraduates with science and engineering degrees, delivering almost one quarter of first university degrees in science and engineering globally.

The U.S. also trails the E.U. in total doctoral degrees awarded in science and engineering, with China rapidly gaining. Since 2007, China has awarded more Ph.D. degrees in natural sciences and engineering than any other country. As our share of trained Ph.D. researchers falls, so will our share of future research output.

China has been transparent about its goals in research and wants to lead the world in key areas.

Let me give you an example of where China is ramping up its research resources in an area historically dominated by the United States—weather satellites.

Last year, China launched 38 satellites, more than any other country, as it attempts to catch up with the West's satellite infrastructure. China's government has made conquering space a key strategic priority, with the Nation's reported \$8 billion space budget second only to that of the U.S., according to the American non-profit Space Foundation.

At UW—Madison, we take satellite research seriously and have long had one of the top-ranked research departments in this field. Our Space Science and Engineering Center (SSEC) and our Cooperative Institute for Meteorological Satellite Studies (CIMSS), an internationally renowned satellite meteorology research center, hold the world's largest, online and publicly available geostationary weather satellite data archive. This archive provides high quality, geophysical data to researchers who study weather and to industries affected by weather, from agriculture to energy and aviation.

The University of Wisconsin—Madison has long been a strong proponent in the international sharing of satellite data, going back to the early days of Verner Suomi, who is often referred to as the father of satellite meteorology. As a result, the U.S.

and Europe have partnered on numerous agreements to share weather data from our respective satellites.

The U.S., however, is not staying ahead of international competition. In the 21st century, China has become an important co-equal partner in the global satellite observing system.

For example, the Chinese recently launched the Geostationary Interferometric Infrared Sounder, the world's most modern geostationary satellite weather monitoring system.

While they developed the technologies to build and launch the instrument, they were building on widely used and published design concepts that originated at the University of Wisconsin.

Today's basic scientific research is the foundation on which future advances in technology, health, and productivity are built. Countries expanding their R&D investments will reap the benefits in future decades. The U.S., with reduced investments in science, will no longer be the future leader in innovation.

My second major point is that the relative decline in U.S. research leadership is not inevitable; we can take steps to maintain our long-term leadership in innovation and discovery.

I urge you to continue to provide meaningful and predictable annual budget increases that support basic and translational research at our Nation's universities. At a minimum, if we don't want to lose ground, research funding increases should match with the rate of inflation. But funding must grow even faster if we want to catch up with our competitors.

In addition to assuring that basic and translational science is funded at America's leading research universities, we also need to improve the commercialization of federally funded research. Supporting the rapid and efficient transfer of information from academia to the private sector, as well as among researchers worldwide, is necessary if we want to achieve maximum benefit from new technological advances. This requires effective collaborations.

Federally-funded research discoveries often provide the basis for innovations commercialized by the private sector. This public-private partnership has been critical to U.S. leadership in both manufacturing and the biomedical sciences.

Let me highlight some examples in medical research. Entrepreneurs, such as those at UW—Madison, have been instrumental in helping to advance areas such as stem cell research, organ transplantation, gene therapy, computerized X-ray images of blood vessels, brain plasticity research, head injury treatment, and asthma research.

According to a recent article in the *Proceedings of the National Academy of Sciences*, all 210 new molecular entities approved by the Food and Drug Administration between 2010 and 2016 were associated with NIH-supported research. Importantly, 84 of those new drugs involved a newly discovered mechanism of action or biological target in the body.

The commercial opportunities created from NIH research fuels our economy and creates jobs. According to an updated 2019 report, NIH research funding in FY 2018 supported more than 430,000 jobs and generated nearly \$74 billion in total economic activity nationwide.

Of course, this research isn't important just because of its effect on jobs. The long-term effects of this research are crucial to advances in human health. Investments in cancer research, including projects at UW—Madison, have helped reduce the death rate from all cancers in the U.S. over the past two decades, according to the American Cancer Society. As of 2015, the cancer death rate for men and women combined had fallen 26 percent from its peak in 1991, translating to nearly 2.4 million lives saved.

In 2009, six economists published a large study entitled *An Economic Evaluation of the War on Cancer*. They look at cancer outcomes between 1988 and 2000, which allows time for the early research to show results in clinical practice. Their analysis indicates the likelihood of cancer survival (across all cancers) improved markedly between 1988 and 2000. By their analysis, 80 percent of the increase in survival was due to better treatment as a result of research advances. Over this time period, that adds up to 23 million additional years of life across the U.S., years that these patients can enjoy with their families.

Beyond the positive results that emerge from research findings, Federally-funded research at universities also plays a critical role in training the next generation of scientists by supporting trainees with individual fellowships and institutional grants.

To build the STEM workforce this country needs, we must continue to invest in training for highly skilled graduates in the STEM fields. These students build their skills by working with faculty on research projects.

Thank you, Senators Gardner and Peters, for co-authoring the American Innovation and Competitive Act, which was signed in 2017. This bipartisan Federal research and technology policy not only maximizes basic research opportunities, reduces administrative burdens for researchers, encourages scientific entrepreneurship, and promotes oversight of taxpayer-funded research, it also promotes diversity in STEM fields, incentivizes private-sector innovation, and boosts manufacturing.

There are three aspects of that policy that are key for the future of American scientific leadership. The Act:

- *Promotes diversity in STEM fields* by creating a working group to study how to improve inclusion of women and underrepresented individuals in STEM fields, and reaffirming the necessity of broadening participation in STEM fields through NSF programs;
- *Bolsters scientific entrepreneurship* by authorizing the successful I-Corps program to help scientists move their research from the laboratory to the marketplace; and
- *Reaffirms the importance of commercialization* by directing NSF to continue awarding translational research grants and strengthening public-private cooperation.

We also need to invest in new and mid-career researchers. I commend Congress for passing the 21st Century Cures Act, and including the Next Generation Researchers Act in the bill, as championed by Sen. Tammy Baldwin. This law is a big step in the right direction. These initiatives will expand opportunities for new scientists and promote growth, stability, and diversity of the biomedical research workforce.

Today, significant challenges loom before us: The opioid epidemic is a national public health crisis. An aging population will mean increased incidence of heart disease, diabetes, kidney disease, arthritis, and cancer. Recent weather patterns threaten coastal areas. America's infrastructure is aging.

America's research universities are working on these challenges. We know that addressing such complex problems will require us to reach across disciplines in areas such as global health, agriculture, language, political studies, climate, and many more. At UW—Madison, we embrace collaboration as a means of accelerating discovery.

Such work goes faster when we share ideas and best practices with scientists around the world. But we also know these collaborations must be thoughtful and in our best national interests.

All of this requires a stable environment in which the R&D enterprise can thrive.

The partnership between the Federal government and research universities is long-standing in the United States and has produced an unparalleled set of discoveries and inventions that have improved lives around the globe. With the challenges in front of us, this partnership needs to be even stronger now than in the past. This means stable and predictable research funding to build labs, experiment with new ideas and complete long-term research projects. It means training the next generation of scientists by supporting trainees with individual fellowships and institutional grants. It means prioritizing science in the Federal budget.

With this type of investment, the U.S. will maintain its excellence in cutting-edge research.

Thank you.

Senator BALDWIN. Thank you.

Chairman Wicker, would you like to begin the questioning?

Senator WICKER. Well, you're very kind to do that and I don't mind if I do.

Thank you all. We appreciate where you've been and where we're trying to bring the Nation.

Let me just start off with my fellow Mississippian, Dr. Shaw. You mentioned on Page 3 of your testimony four themes and the first of which is "investment must be broad-based geographically. We must support the best and brightest students and researchers wherever they are, not just at a few locations."

I'm told that NSF says that nearly half of all funding in the last two decades went to just six states. I guess that's what you're talking about in terms of being broadly funded geographically.

So how is this a problem and speak to what we might be able to do about that, Dr. Shaw.

Dr. SHAW. Thank you, Senator Wicker.

No one would argue that we all have talented and intelligent students and researchers in every state in the Nation. If we as a nation intentionally set out to fully reach our potential, every young person must be given every opportunity to reach that potential.

The established program to stimulate competitive research at NSF and EPSCoR Alike Programs at NIH, DoD, USDA, and other agencies are specifically designed by name to stimulate competitiveness in research across the Nation. These programs have and continue to evolve and do just that and are fine examples of how to ensure that every student has a place at the table.

As we continue to see industries of the future develop, such as quantum computing, 5G technology, artificial intelligence, we do not need to see have and have-not situations exacerbated. It is only in the best interests of our Nation for all to be haves.

Senator WICKER. Well, tell us about EPSCoR. I understand it is an experimental program but it has lasted quite a while. It obviously isn't working as well as you hoped it would.

Dr. SHAW. Well, I think a lot of that depends on how you define "working" because the states that are receiving EPSCoR funding either through the Track 1 or the Track 2 and Track 3 Programs certainly have used those funds effectively to be able to develop graduate assistantships to be able to have researchers develop. In a hyper-competitive environment, as several of the speakers have referred to, our states are continuing to be able to compete because of that.

Now have they gained ground? No, in many cases, that's not the case. But have they lost ground? No, it has stimulated competitive research.

Senator WICKER. Dr. Souvaine, is this a problem, geographical inequity, and how is EPSCoR working?

Dr. SOUVAINE. I think if you look back to the NSF Act, it charges us to strengthen research and education and science and engineering throughout the United States and to avoid undue concentration of such research and education.

This needs to be a priority, balanced and aligned with a need to fund the best proposals, so every American should benefit from the science and engineering economy and the science and engineering economy needs the talents of every American.

Now that's something that spans all sorts of different levels. We've recently issued a Skilled Technical Workforce Report that talks about the need for a STEM-capable workforce everywhere in the United States and every job needs more STEM than they used to but right now, there are a whole bunch of jobs that require not a four-year degree but require maybe one or two years post high school, if done in concert with what we were talking about earlier in the testimony, of working together with industry and partnerships with community colleges and partners with higher ed and partners with the local school districts and the local government.

Senator WICKER. So should we be concerned that over 20 years, more than one-third of all Federal research funding has gone to two states?

Dr. SOUVAIN. I think I would not look backward but would look forward. The texture of science and engineering going forward from today requires all of our talent and we need to look at it as how we're going to develop it across the entire country.

Senator WICKER. OK. Thank you. Thank you, Mr. Chairman.

Senator GARDNER. Senator Sullivan.

**STATEMENT OF HON. DAN SULLIVAN,
U.S. SENATOR FROM ALASKA**

Senator SULLIVAN. Thank you, Mr. Chairman, and I want to just throw this out for all the witnesses. By the way, thanks for holding this hearing. I think Chairman Wicker's question on where the research dollars are going is also a really important one, I think. So maybe we can follow up with more questions on that.

But, you know, with regard to marine ecosystems and the importance of Federal research as it relates to making sure we understand what's going on in the oceans, which is very important not just for my state, Alaska, for the fisheries there, but I think for the whole country, whether you're on the coast or not.

How do you think the Federal Government can be enhancing that research, particularly with universities and partnerships that give us a better understanding of what's happening, either the pollution, you know? We've held a number of hearings on the issue of ocean debris and ocean plastics, or making sure we have sustainable fisheries.

NOAA's mission, the Federal Government's mission is to make sure we have that data, but a lot of times the data resides in universities and other scientific organizations that aren't necessarily Federal Government organizations.

I'll throw that out to any and all the witnesses because it is a really important issue for my constituents.

Dr. BLANK. I'll start with that. I'm a little more familiar with the freshwater coastlines than saltwater coastlines, but NOAA and, you know, the Sea Grant Programs have just been a wonderful partner with universities in terms of working together.

We sent students back and forth to various projects. We work together closely with personnel in those agencies and there's a constant sorting out of what are the next set of questions that we need to be looking at, such as changes in ocean temperatures. That's happening in the lakes in Wisconsin, as well, that you see complete changes in fish populations.

I know you're seeing that in the oceans, also. There's a whole new set of pressing questions. Federal funding leverages the research that NOAA and other organizations do with the research that the universities do, so these efforts become synergistic and build on each other. This is very important.

Senator SULLIVAN. Great. Anyone else?

Dr. PANCHANATHAN. Senator Sullivan, thanks for the question.

I think a couple of things stand out. One is how might we promote more interagency partnerships around these grand challenge problems. This would be one of those problems. How do we promote that kind of a partnership? How do we promote partnership between the private sector, the universities, and the nonprofits who are also participating in these investments,——

Senator SULLIVAN. Right.

Dr. PANCHANATHAN.—and so how do we then make data available that is then shareable across all of these platforms? So that might be something that we might want to think about.

And you touched upon the issue of sustainability, which is, I think, an important element. How do we make sure that we are all working toward a sustainable future? This is something that the university—I mean, since I come from ASU where we have a School of Sustainability,—

Senator SULLIVAN. Yes.

Dr. PANCHANATHAN.—we focus a lot and we work in fact, in partnership with universities across the Nation and beyond to see how we might find problems that we all can work together on and solve them.

So more such partnerships among universities, among agencies, as well as with nonprofits and the private sector, are the only way we can solve such grand challenge problems.

Last, I will leave you with this. I think increasingly universities are recognizing that when you really want to solve a problem, it is not just a science problem or an engineering problem, but a behavioral problem or a social problem or a cultural problem or a policy problem. It is all of the above and more.

So universities are starting to see how you can assemble teams that bring people across disciplines so they can work together to find meaningful solutions rather than just one slice of a solution.

Senator SULLIVAN. Good. Thank you.

Anyone else? Dr. Shaw?

Dr. SHAW. Senator Sullivan, thank you for the question, and I certainly agree with my colleagues.

I would just simply add that there are some mechanisms in place that will certainly allow more of what you're talking about and I think the word "partnership" has been used several times. We're a part of a cooperative institute, which is a Federal program that NOAA has to be able to specifically partner the agency with universities and consortia to address specific topics.

The one that we're a part of is focused on the Gulf of Mexico—

Senator SULLIVAN. Right.

Dr. SHAW.—but there are a number of these and they range from atmospheric focus to ocean and atmosphere combinations, and so I think these types of things need to be supported heavily because it does provide the opportunity for that cross-collaboration across agencies but also with university sector to be able to bring the kinds of partnerships that Panch has mentioned.

Senator SULLIVAN. Good. Thank you. Thank you, Mr. Chairman.

Senator GARDNER. Thank you, Senator Sullivan.

Senator Blumenthal.

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

Senator BLUMENTHAL. Thank you, Mr. Chairman, and thanks for having this hearing. Thank you all for being here today.

Let me ask the two—well, let me ask all of you. I was going to say the two female members of this panel, but I'll ask all of you.

How are we doing on non-discrimination based on gender in science? I'm saying this as a layman who is simply reading what's out there and hearing perhaps some of the complaints. Is this an illusory issue or is it real and, if so, should more be done about it?

I'm willing to start and just go right down the panel.

Dr. SOUVAINE. I think there are two different things to look at. One is discrimination and the other is encouragement and we need to stop the one and enhance the other.

I think discrimination still exists, but I think that we're all coming together to try to work on that and to try to make change. I was very pleased with the NSF policies that were set earlier this year relative to sexual harassment. I think that's really important.

But I think that we all need to change our definitions of what it means to be a scientist or an engineer and to challenge any unacknowledged biases we might have as to what a scientist or an engineer looks like, how that person speaks or what that person does, and as we change that, we'll change that both for who are the representatives of science and engineering as professionals, but we're going to change everything down to which kids in kindergarten are doing things that are scientific and mathematics in their free choice period and where things are going to go from there.

There's a lot more work to do. In our demographics, we can say that we've made significant progress in the last several years in terms of broadening participation. There are a lot more women, there are a lot more Hispanics, there are a lot more blacks going into science and engineering, but if you look at the proportion of the whole, we're not making very much advance.

So the literal numbers are going up but not the proportion. So we have a lot more work to do.

Senator BLUMENTHAL. Well said. Dr. Shaw?

Dr. SHAW. Thank you, Senator. It is a great question and we certainly recognize that it has been a challenge and it still is a challenge.

I guess I would say coming from the other direction, though, as we bring in cadre after cadre of our young scientists, young faculty, it is very encouraging to see the changes that are taking place very rapidly in our universities, and I believe that they are bringing in a fresh look, a fresh enthusiasm, and a set of values that are quite different than what we've seen in the past.

Do we have room to grow? Absolutely. Have we made a great deal of progress in attitudes? Absolutely.

Senator BLUMENTHAL. Thank you.

Dr. PANCHANATHAN. Thank you, Senator Blumenthal, for this wonderful question.

I find with any problem as this or any other problem, first, we need to identify the problem and recognize it as an important problem that we need to solve. Then we need to commit to solving them. Lastly, most complex problems, which have not had solutions in the past require innovative ways of solving them, so as a framework of thinking.

Now what have we done at Arizona State University to change this? More than half of our student population are female, and our Engineering School had a very low percentage of female students. So we took that as a problem that we need to solve, and then you

commit to solving them, as I was saying, and then we said let's start to address the K through 12 system.

How can you actually bring students from the K through 12 system and excite them about STEM disciplines? That's one methodology that we used. The other is we asked the question, where are the female students going to, and typically it happened that most of them were going to social sciences, humanities, and the arts.

So can we then bridge social sciences, humanities, and the arts back into engineering and computer science, for example, through minors that they can take, so then they get attracted into taking a minor and slowly start to make it their major.

So how do you find other ways in which you can bring more awareness to this and solve the problem?

Last, but not the least, is role models. If we don't have enough role models, we will not be able to change this. So what we have done at ASU is that we've changed the culture of the institution itself by having leadership and the presence of a number of role models that inspire students to want to pursue science, technology, engineering, or even higher education, for that matter. So those are the ways in which you can change.

Culture change, as you know, is hard, but that's why I talk about the commitment to do that, and thank you for the question—

Senator BLUMENTHAL. Thank you.

Dr. PANCHANATHAN.—and looking at it.

Senator BLUMENTHAL. Thank you.

Dr. BLANK. So we're not where we need to be for women in science and women in STEM. There are a few areas, like biology, which have heavy representation of women, but there are a lot of areas in computer science and in engineering where we just have way too few and if we want to increase the numbers there, the best thing we can do is get our entire population interested in these fields.

I would note that a lot of women come into college already convinced that science is not for them and you've got to work on the pipeline issues here in K-12. That's Number 1.

Number 2, there are often special things you can do to make sure that you are supportive of women who are in fields where they're a minority. So, for instance, we have a residential living community for women in engineering, which does special advising and activities and talks about, you know, the ways in which engineering impacts social outcomes in the nation. This show that engineering is more than just a set of technical issues.

Third, the curriculum does matter especially introductory classes in how engineering is taught. Also advising, role models, mentoring, and, of course, that's a chicken and egg problem because you've got to get women ready to teach and to be in the profession.

Senator BLUMENTHAL. Thank you.

Well, these answers are excellent. If any of you have other—I know you're limited in terms of the time, but if you have other thoughts or ideas about this issue because I think it is one that, to the extent we can be helpful, we have an obligation to do so.

Thank you very, very much.

Senator GARDNER. Thank you, Senator.

I should have mentioned at the outset that we were going to have votes right in the middle of our opening statements. I apologize for not doing that, but I voted. Senator Baldwin is now voting and she will be back, and we have another vote coming up. So we may be doing this one more time. So I apologize for that.

I'll go ahead and start with my questions. You know, I'm struck because so many of you participated in our first effort through this committee to reauthorize the American Competes legislation and we did for the first time in a decade with the American Innovation and Competitiveness Act and so thank you for your work on that legislation.

I remember at the time Dr. Drogemeier saying to this committee thank you for making science bipartisan again. Many of the issues that we brought up in these and the questions I've heard from my colleagues have related to some of the same issues that we were trying to address then.

So I want to get into some of the results of that legislation and how we're doing, maybe a progress check on that, but also what we can be doing to continue to improve, as you've mentioned to Senator Blumenthal and others.

So I want to start with this question. I was struck by a visit I had to the Middle East years ago and we were traveling to Amman, Jordan, and it was dusk. As the airplane was nearing the airport, I'm looking down thinking about the meetings that we were going to have, meetings with policymakers, scientists, opportunities in the Middle East, and as I looked out at Amman, I saw streets that were crowded with cars, massive traffic jam, lit up by street lights on the corners and an airplane, and I'm thinking every single one of these innovations has helped make the United States such an incredibly strong place.

Cars that are generations descended from the assembly line mass production, lights that were generations descended from Thomas Edison and others, on an airplane generations descended from American inventors, but those are all here in the supply chains and the jobs and the innovation that went with all three of those sort of societal-changing events occurred here.

What happens when that next big idea, that next big invention, that next big thing is not here in the United States, but it is in China, it is in India, it is in Africa, it is in Europe?

Dr. Blank, from an economic perspective, what happens?

Dr. BLANK. So the science itself moves fast. When people get a new idea or hear about it, you know, folks grab on to that quickly.

The biggest effect of having a major invention that isn't in the U.S. or inside Western powers is how it spreads in the regulation and use of it. So almost all of the major inventions of the post-World War II era have been in the West and they have been under the regulation of a common set of rules.

If 5G, AI, other things start emerging faster out of China, there will be a different regulatory regime there. Think about some of the medical advances that could be happening and that will result in very different types of use. It is a real interesting question of what happens if something comes out as under one regulatory regime and then when it moves into more Western societies, they want a

different regulatory regime and how do those two impact each other.

It will certainly slow the expansion of these new inventions and could lead to some very real political clashes.

Senator GARDNER. Thank you.

Anybody else on the panel wish to address that? Dr. Souvaine?

Dr. SOUVAINE. I think one of the things we want to be careful to do is to make sure that we are always at the table and so that means that we've got to continue to conduct our science and engineering enterprise consistent with the principled traditions that have yielded us success over the last 70 years and the benefits it realizes from nurturing a global community of similarly principled partners so that then as inventions are developed in one country or another, we have a shared culture, a shared understanding of what's fair play and how we interact with each other.

We don't want to ever be away from the table. We don't want to be surprised by an innovation that occurs somewhere else. We want to be always right there at the frontier of knowledge and so that's something that we have to be careful about.

Senator GARDNER. Dr. Souvaine, in your testimony, you talked a little bit about the 2018 Science and Engineering Indicators Report the National Science Board released, and you talked about how China accounts for nearly one-third of the entire global increase in research and development spending from 2000 through 2015.

Meanwhile, here in the United States, our research and development global spending declined from 37 percent to 26 percent. Our allies in Europe witnessed a decline in their share of global R&D, as well, dropping from 27 percent to 22 percent, and I think, you know, you've outlined some of the concerns when that happens.

We spend, I think the number is about 2.7 percent of our GDP on research and development as a country. China is now spending about 2.1 percent of their GDP. I think Japan, Germany exceed the United States in terms of GDP.

So a couple of questions. Are we at the table? We're at the table now, but is there a real risk that within the next 5 years, we are no longer invited like we were, lose that understanding of what is being invented?

The second thing is do you have an idea, and I'm going to run out of time here and maybe we can address the second question next round, what should the United States target GDP investment in research and development be?

So why don't we go ahead and start with the first one on are we at the table now? Do you see that change—we are at the table now, but do you see that changing in the next 5 years?

Dr. SOUVAINE. I think we are at the table now and we need to continue to be at the table. That's going to mean that we need to think about what our global partnerships look like.

Yesterday, I spent the day at a meeting of a task force at the American Academy of Arts and Sciences that's looking at large-scale science partnerships. We need with new research facilities—we don't need multiple ones of them. We need international ones that we have good partnerships running and that are accessible to scientists across the world.

That means we need to be able to be a good partner and sometimes things that get in our way are not having multi-year funding. How do we commit to being a good partner? We need to make sure that we are at the table talking about our principles and helping contribute to the discussions about the ethical compact that all of the partners will follow willingly because they've helped develop it together.

Senator GARDNER. Very good point. Thank you.

And I'm going to interrupt you there because I want to turn to Senator Baldwin, but we can continue the conversation in the next round.

Senator Baldwin.

Senator BALDWIN. Thank you, Mr. Chairman.

Chancellor Blank, as you noted in your testimony, the United States is rapidly losing its competitive edge in research and STEM education investments.

I wanted to start by drawing on your experience having both been a leader at the Department of Commerce as well as Chancellor at the university and in academia.

Can you speak to the impact of government investment in research on U.S. industry?

Dr. BLANK. Research is funded by both industry and by the Federal Government. Industry-funded research tends to be much more applied and specific. Government-funded research tends to be a little bit more basic and the synergies between those two that are important, you don't get the specific inventions without doing the basic research first. So virtually all of the new devices that we have in our homes and in our pockets came out of research in the 1960s, 1970s that had no obvious application whatsoever at that point in time.

There is a need for the Federal Government to fund that basic research which economically no industry is going to put money into. That is what really makes the Federal investment in research quite crucial and quite important. The investments we make today may not pay off in terms of economic value until 30, 40, 50 years from now, but if we don't keep that investment going, the river will run dry.

We won't experience it next year, but in 30 years, we will definitely be quite a ways behind other countries.

Senator BALDWIN. I want to continue and focus a little bit specifically on Wisconsin, our innovation strengths and weaknesses, to help me better understand what changes we might need to make in Federal research programs to focus on Wisconsin.

As you know, we have something called the Wisconsin Idea. We're very proud of that. It is kind of the idea that the university and research should help solve problems and improve the lives of everyone in our state. Sometimes the Wisconsin Idea, we think of it as the whole globe or beyond.

But while we have a very vibrant innovation and startup community in the Madison area, some other parts of the state are still lagging behind and so let me just ask a couple of questions regarding that.

What are some of the challenges that you see in our state that prevent Federal research programs from furthering the Wisconsin Idea and helping fuel innovation all around the state?

Dr. BLANK. It is a good question. So Federal research tends to go to professional researchers which means it comes into the universities of Wisconsin and, you know, we had an earlier conversation here about how widely spread the research funds were.

Certainly spreading research funds to younger investigators, spreading research funds, particularly more applied research funds, to a wider variety of institutions could well be helpful. It is also true that what the institutions do with those dollars matters, and, you know, the Federal dollars rarely pay for projects out there in the hinterland, right out of the university. I think universities need to be encouraged and incentivized—many have those incentives anyway—to make sure that we are not just doing the work inside the labs but we actually get engaged and engage our students and our staff and our faculty with thinking about what the implications of that work is for something that can actually have a long-term useful purpose.

Senator BALDWIN. On this same theme, what do you see as the biggest strengths and biggest challenges with our Federal research programs that directly lead to innovation and a startup economy?

Do you have specific suggestions for changes to any Federal research programs that would help better support economic growth in states like Wisconsin?

Dr. BLANK. So if you ask me what are the biggest challenges, one is the funding that goes disproportionately to more senior researchers, and I think focusing more money on younger researchers is a very—

Senator BALDWIN. I have another question on that in a moment.

Dr. BLANK. Yes, yes.

Senator BALDWIN. Go ahead.

Dr. BLANK. You know, my second comment is that I think there's a real advantage—and I know NSF and NIH have been doing this—in picking some big problems in society and focusing dollars around them, whether that's brain science or quantum computing. The Federal Government, you know, has a convening role of bringing together institutions from around the country to do this.

My third comment is I think one of the most effective things that the Federal Government has done, and this is not standard research funding, it came from elsewhere, were these partnerships between manufacturing, industry, universities, and state and local governments that were under the Obama Administration. They were focused on specific problems. Different areas bid for them and brought together a wonderful coalition between industries, the universities, and the civic society and really created some real paths forward on things like 3D printing and a whole set of different issues.

I would wish that we could continue to follow that model.

Senator GARDNER. We'll go back and forth so you can continue the question.

Dr. Souvaine, I cut you off earlier. Did you want to add a little bit to that answer?

Dr. SOUVAINE. Yes, a couple of things.

You asked a question about potential GDP——

Senator GARDNER. Right.

Dr. SOUVAINE.—as part of the question we didn't get to at all. There was also an earlier question.

I don't know the answers to that. I wonder whether 3 percent, which we've been at, I believe, in the past but we are not now, would help put us in the right direction.

I do think that we need to do a right-sizing, if you will, of NSF. I think that basic research actually addresses some of Senator Baldwin's concerns, as well, that as Dr. Blank said, it is a basic research result that then goes the distance and leads to something that's commercialized.

As we saw, a Nobel Prize winner recently, who had basic research funding from NSF in chemistry for years and years and years, and that led to the lithium ion battery which we're all quite familiar with.

If you look at patents, there's an interesting statement about where patents come from and it is interesting because all of our agencies help us get to patents and I guess I'm not going to find it at the moment, but it is fascinating to me that given the smaller funding for NSF that in fact a lot of patents come from the NSF basic funding initiatives and in the same way venture capitalists have talked to us about their concerns.

They're very concerned that we're maybe not funding enough high-risk/high-potential gain basic research and that in 20 years, they're not going to have things to commercialize in this country and that they will be going elsewhere.

Senator GARDNER. There would be nothing in the pipeline to bridge that commercial stage?

Dr. SOUVAINE. Right. The crazy idea that NSF funds now that you don't know that it is going to pay off. Companies are not going to fund something that they don't see a line to profit and yet the initial research that led to the lithium ion battery, they had no sense that it had an application. It was just a pie in the sky chemistry study. It led to something that was really important.

If we don't fund enough of those things that are curiosity-driven, that are inspirational, the ideas of our talented researchers now, then in 20 years, we don't have the pay-offs that we need to get.

Senator GARDNER. Right. And I think that's what I'm trying to get at with the question of whether we need to set a national goal.

You know, Dr. Blank mentioned it in terms of some of the science that's taking place at NIH in terms of setting a goal on a big issue and so should we as a country have a goal that we aspire to and reach for and that we know and that's why I asked the GDP question.

I don't know if anybody else wants to comment on the GDP question about what we should target it to so we can build to it. I mean, I took a tour of the NIST facility and this committee is strongly supportive of increasing funds for NIST which we have done, but one of the labs had a barrel with a plastic trash sack in it to collect water because the roof was leaking where Nobel science research is taking place and now we are replacing those facilities, but that never should have gotten in that condition in the first place.

I want to ask another question, too, about just how we continue working on getting more people to the United States.

Dr. Panch, I think you talked about this. Dr. Souvaine, you talked about this. If somebody is a budding scientist somewhere around the globe, are they still looking to the United States?

Dr. PANCHANATHAN. I think they still are, because if you look at the kind of research that happened at our research institutions, I would say that there is nothing equal to what we have in the United States, but we need to be more welcoming of such talent and aggregate the talent here.

In fact, I often say, you know, when we talk about the Thousands Talents Program in China, why not have the 10 Thousands Talents Program in the United States?

Senator GARDNER. Right.

Dr. PANCHANATHAN. Let's play offense rather than defense. I mean, this was something that was talked about earlier. You know, instead of trying to be, you know, protecting, which is important, but it is also important that we show that we are the place that people need to be here because we are the place that shapes talent.

I mean, I'm an immigrant and this country gave me this wonderful opportunity to exercise my talent, and I'm ever so grateful for the opportunity because here I am.

So I think there is a lot of such talent that is not only domestically available that we need to nurture and bring out, which is what universities like ASU are doing. The socio-demographic of talent that is out there, aggregate all the talent and make sure that you provide them the highest-quality education, but also welcome talent from across the globe so that we might be the place that they see that they can do something really creative and innovative.

I just want to—if I may, the previous question that you asked about what happens if things get invented outside of the United States. I say, well, fine, let's take that and see how we can bring it out of the marketplace faster than anybody else can. We have the experience here. We not only have the basic science, which I think—you talked about the GDP.

I would second what Dr. Souvaine said, that we should be probably at 3 percent of GDP, maybe more, who knows, but I think we are in a global race right now, which means that we need to double down and invest more on basic research. That's absolutely paramount for us to bring the talent and not have the cutting on the sharp in terms of the 1.5 billion that is less for not being able to fund fantastic ideas.

So we need to do that, and then we need to take those ideas then to see how we can translate them through partnerships. It is suggested 73 percent of our 542 billion of R&D is in businesses. How do we take the partnership to take that as well as the interagency partnership, other agencies, which have a mandate, mission agencies, to take ideas and then translate them into, you know, products and services?

So that's what we need to focus on. How do we get more of a pipeline of ideas from the basic science to the end product, partnership with industry, aggregation of talent from across the globe? We have to look at all of the above and more in order for us to be in the vanguard.

Senator GARDNER. Thank you, Dr. Panch.

And then I'll turn it over to Senator Baldwin. One last question on the young investigators. How do we get more of the dollars, grants, programs to these younger scientists, researchers that you're talking about? Is it a matter of saying we're going to have X percent of dollars are going to, you know, the first 10 years of work? Is it something else? I mean, how would we do that?

Dr. BLANK. I think you have to have some very explicit guidelines about what percentage of dollars, or what types of projects are targeted on younger investigators. That will mean probably limiting some of the multiple RO1 grants to more senior investigators, but we've got to be keeping our feed corn growing, right?

Senator GARDNER. Because I think in the previous panels, we heard that a person may only get one grant or one shot at dollars from NSF or others throughout their entire career and maybe it happens 40 years into the career, maybe it happens 3 years into the career, but we should be doing better than that, I think.

Senator Baldwin.

Senator BALDWIN. Thank you, Mr. Chairman.

My questions really dovetail with your question. In 2016, President Obama signed the 21st Century Cures Act which included my Next Generation Researchers Act. This law was focused on NIH.

It was focused on NIH promoting opportunities for young researchers, and it was a real interest of mine as I truly encountered folks who were attending the University of Wisconsin—Madison with the dream of curing something or solving some mystery and yet recognizing in their academic training that the average NIH major first grant is given to somebody who's around 43 years old and after all that training and postdoc training, et cetera, they've got to have a lot of faith in those opportunities.

So what it directed NIH to do was really promote opportunities, very targeted opportunities for young researchers, both intramurally and extramurally, to coordinate the programs in a single office that was focused on this issue, and, also included mentorship and other opportunities along that thinking.

What I want to ask, and I guess I want to start with you, Dr. Panchanathan, close?

Dr. PANCHANATHAN. Yes, very close, very good.

Senator BALDWIN. We have other Federal agencies that fund research. What sort of approach would lend itself to developing that next generation of researchers in other Federal agencies? Would that same model work for NSF or others, or would you promote a novel approach in other agencies? What are best practices in this regard?

Dr. PANCHANATHAN. I think fundamentally, talent, idea generations and talent is something that we should focus on. Whichever agency that it is, it doesn't matter. It is about ideas and it is about talent.

Then the next question is, what do we focus on in each agency? Mission agencies are specific missions in terms of what they need to accomplish. So they need to not only focus on ideas and talent, but how do you take that into what the mission is to be supported for, in the case of NASA or Department of Energy, having both Office of Science as well as the EER and others.

NSF clearly is about ideas and talent. We need to build that at scale. Our future is guaranteed in terms of competitiveness only if we have the ability to be able to invest sufficiently to have these ideas and talent at scale. We will lose otherwise.

So I think this is very important, and the point was made very clearly. So I don't want to over-emphasize it, but it is to be emphasized that that is an exceedingly important imperative.

So each agency has to determine how that concept of ideas and talent can be scaled, and then shape it to what the specific mission is. So if it is DARPA, then take a grand challenge problem, ideas and talent again, but then solving the particular problem. That's why I'm bullish about this fact and why I started this with my comments in my statement. These big ideas that we are working on are the ways in which you get to be highly competitive by picking those areas, like industries of the future. These areas are being picked because we can be globally competitive in that area and we cannot lose ground.

So you pick those areas and make that your mission and that mission is shared mission. Sometimes the missions are specific to agencies but some are shared missions. AI, to me, is a shared mission. Every agency has to make sure, and that's why I'm again very delighted to see the White House efforts in terms of bringing the interagency efforts around AI.

We need to do more of that in my view, and then bring in industry partners and other nonprofit agencies and foundations who are also investing a lot of resources, all to the table so that we can solve them together.

I hope I answered your question.

Senator BALDWIN. Thank you.

Dr. Blank, do you have anything to add on this idea of supporting the next generation? Should we depart from the model we used at NIH, or is that the best practice for all of the agencies that fund basic science at academic institutions?

Dr. BLANK. So I think many of the agencies, including the NSF, as well as NIH and others, fund graduate students, fund postdocs, and that's really important for building the pipeline and gives us larger numbers of graduates in a lot of the science areas than we would have without that funding.

So I don't want to say that we're not providing funding to some of the younger researchers, and then I think there just has to be a share of grants that are directed to people early in their careers. You know, we're losing lots of good researchers because they simply don't want to wait, you know, so far into their career that it is actually age 43 or later before they start setting up their own lab. They're excited about the science. They want to do it sooner.

Senator GARDNER. Thank you, Senator Baldwin, and I think they just called the second vote. So we'll go through maybe one more round, if you want, then probably have to adjourn for votes.

But just we passed the American Innovation and Competitive-ness Act, signed into law in January 2017, right at the end of that Congress.

One of the big focuses in the bill was to make sure that we were sort of reforming, rethinking the way the Federal Government ap-

proaches STEM programs to make sure that we were attracting underrepresented communities, minorities, women, into the field.

Has the Act succeeded? I know we've got more years to go and more work to do. Is it a good start? Have we seen positive traction from that legislation with more to do, Dr. Souvaine? If you don't feel like you can comment on it, then that's fine.

Dr. SOUVAINE. I think definitely there's positive traction, but I think that in light of the last question, as well, I think if one were to look at the \$1.6 billion of highly ranked proposals that were not funded at the last year, I suspect, and I would have to go back and check, that that's disproportionately younger people and so you have people who are submitting really, really strong proposals and they don't really know what else to do to get funded and there's just not quite enough to fund at the level that we funded in the past.

So I think, yes, the Act is doing a tremendous amount of good and, yes, every bit of funding that Congress has awarded to NSF is being put to good use. I'm incredibly impressed by the leadership of NSF and how they're doing all the balancing, and I wouldn't want to skew the way they're making decisions with the funding that's there, but as we go forward, if we can right-size, if we can have an out-of-cycle adjustment, if you will, to get to a point and then sustain from there, but we may have a gap right now in where we ought to be and where we are.

Senator GARDNER. Does anybody else wish to answer that question?

[No response.]

Senator GARDNER. OK. Dr. Shaw, in your testimony, you mentioned partnerships with the private sector.

Is there anything we can be doing right now to facilitate that? Perhaps there's a regulation that's getting in the way. Is there something more we could be doing from an incentive standpoint on the collaboration and partnership front?

Dr. SHAW. I don't know that there's a lot of regulation that needs to be removed as much as there needs to be an overt and very conscious effort to really put more focus on that.

One of the programs that I mentioned in my testimony was the FAA Center of Excellence that we have with unmanned aircraft systems. That program actually requires a one-to-one cost share from the private sector or from non-governmental sources.

We questioned this when the award was made, but at the same time that's been a huge blessing for the research programs because at the front end, it brings industry in to help sharpen and define what the real issues are that need to be addressed with these funds. On the back end, we have a ready recipient to be able to receive the results and put it into implementation.

And so I think we need to be thinking more about the requirements that we have or the opportunities that we're creating. It was earlier mentioned the opportunities that have been created with some other Federal programs that required public/private partnerships and I think we need to expand and explore other opportunities.

Senator GARDNER. Thank you.
Senator Baldwin.

Senator BALDWIN. We're finding just an enormous demand for workers with STEM skills, including some individuals who might not require a 4-year degree. I know in Wisconsin, manufacturers are struggling to find fairly high-skilled workers and finding a skills gap.

I'm also a member of the Senate Health, Education, Labor, and Pensions Committee, and I'm keenly interested in how we coordinate Federal support for developing a strong STEM workforce in K through 12 and postsecondary education as well as workforce development programs that exist.

Dr. Souvaine, I know that the National Science Board has just completed an examination of the skill technical workforce and I applaud that effort.

I'm wondering what role that examination suggests the National Science Foundation play in developing that technical skilled workforce.

Dr. SOUVAINE. I think our sense is that this is larger than any one agency or foundation but certainly, we're guiding the NSF to do a portfolio analysis to try to understand where all of the parts of programs that they're funding now are impacting this, hopefully positively.

We also talked about the fact that the data just are not integrated enough across agencies across the country to really understand exactly where we are in this domain. So we have NCSES is working together with other statistical agencies and other colleagues at various different agencies to try to look together. I think they have a conference coming up in the next month, a workshop where they're working together to pull data together to look at what kinds of things need to happen next.

So I think there's going to be a lot of work to do. Where can we interface with higher ed, with community colleges, with industry, with other Federal agencies? I know one example, and I'm sorry that Senator Peters had to leave already, but we were doing site visits and listening sessions around the country and we were in Michigan and saw there an example that really seemed to be working very well where Macomb Community College was partnering with Wayne State University, partnering with the Detroit automakers and had students who were doing their post high school training on the same equipment that they would be using if they went to work for one of the Detroit automakers, and they were having terrific teaching at the community college and empowerment of a broad constituency of students and moving forward.

So they are a good example and it is a collaboration funded by NSF on the ATE Program.

There were other examples in other states that we saw and they need to be generalized and how can we go forward? How can we take the best knowledge from the successful ATE Programs and see how within each individual state we can get partnerships with the state government, the state industry, the state universities, and the state community colleges to drive things forward?

Senator BALDWIN. Thank you.

Dr. PANCHANATHAN. I think here is a partnership that we have not talked about in this hearing, which I think is important—the states, cities, counties. They all play a role in terms of building ro-

bust STEM workforce activities. So that's something that we should take advantage of.

And I leave you with one more thought, which ASU has pioneered recently with Starbucks. We developed this training program with Starbucks for the employees who are in the workforce right now. They call them partners. We have 13,000 of them enrolled in ASU programs. This gives them a chance while working in Starbucks to be able to get their four-year degrees, and they'll be productive members of society, whether they continue to be at Starbucks or not, that they are productive members of society.

We need more of these kinds of programs that are available to people already in the workforce that need to re-skill, up-skill themselves because the future of work, as you know, is rapidly changing and so people have to adapt and change. So we need to have that segment also taken care of in addition to developing a robust K to 12 pipeline, as well as giving them community college and higher education opportunities. So all of that is required. It takes a village.

Senator BALDWIN. Thank you.

Senator GARDNER. Thank you, Senator Baldwin, very much for your work on this hearing, and I look forward to continuing to do great things in this committee's progress as it relates to science, R&D, and the STEM fields that we have talked about today.

So thanks to all of you for your time and testimony today.

So this is the homework assignment right now. The record for the hearing will remain open. This is a very gracious two weeks apparently for the Commerce Committee. That's a long time for these guys to come up with things. So two weeks, I apologize for the length of that.

Upon receipt of the questions for the record, I would ask that you submit your responses as quickly as possible and no later than November 19, I would appreciate that. The responses and the questions will be made a part of the official record of this hearing.

So thank you to all of you for your time and testimony today. We look forward to working with you as we find new ways to promote science and retain and grow U.S. leadership.

And with that, this committee hearing is adjourned.

[Whereupon, at 3:44 p.m., the Subcommittee was adjourned.]

A P P E N D I X

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MARIA CANTWELL TO
DIANE SOUVAINÉ, PH.D.

Question 1. According to data in the National Science Board's 2020 Indicators report, American Indians and Alaska Natives are earning proportionally fewer science and engineering degrees than they were in 2000. How is the National Science Foundation engaging tribal colleges to address this decline?

Answer. There have been modest gains in the absolute numbers of bachelor's degrees awarded to American Indians or Alaskan Natives, which increased from 2607 to 2844¹ between 2000 and 2017. I am concerned, however, that enrollment of these groups at 2- and 4-year institutions is declining despite increases in population growth, exacerbating a discrepancy in Native American degree attainment that significantly lags white students. It is important to understand the factors driving these trends at the state level, where culturally appropriate actions can be taken.

For its part, the National Science Foundation's (NSF) Tribal Colleges and Universities Program (TCUP) provides awards to Tribal Colleges and Universities, Alaska Native-serving institutions, and Native Hawaiian-serving institutions to increase Native individuals' participation in STEM careers and improve the quality of STEM programs at TCUP-eligible institutions. Support is available to TCUP-eligible institutions for transformative capacity-building projects such as Instructional Capacity Excellence in TCUP Institutions (ICE-TI) and Targeted STEM Infusion Projects (TSIP).

NSF provided \$15 million for TCUP in FY 2019 and \$15 million in the FY 2020 budget request to Congress. With NSF support, about one-third of the TCUs now offer Bachelor of Science degrees in STEM and STEM education. In 2018, a TCU received Accreditation Board for Engineering and Technology (ABET) accreditation for its Bachelor of Science degree in engineering. The accreditation was retroactive back to the TCU's first engineering graduate, thereby ensuring that all the college's engineering graduates hold ABET-accredited degrees, vastly increasing their employment opportunities. Additionally, with NSF support, TCUs have begun developing accredited Master of Science degrees in STEM fields, significantly increasing opportunities for their students to pursue advanced study and employment.

Broadening Participation Programs. In order to unleash our full economic potential, all Americans should be welcome in the innovation economy, regardless of gender, race, or ethnicity. Recognizing this, the National Science Foundation has invested billions of dollars in programs and research to improve diversity in STEM fields. Despite this investment, the proportion of women earning science and engineering degrees has been relatively stagnant over the past decade.

Question 2. What is your assessment of the effectiveness of the National Science Foundation's broadening participation programs?

Answer. NSF has a long history of investment in broadening participation and, over the past two decades, an increasing number of women and underrepresented minorities have been awarded science and engineering (S&E) degrees and entered the S&E workforce.² However, more work needs to be done to ensure that everyone, regardless of zip code or demographics, may participate in the S&E enterprise. To tackle the most persistent challenge in broadening participation—finding approaches that scale effectively and emphasize institutional transformation and system change—NSF launched its INCLUDES initiative (Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science). As part of NSF's Big Ideas, INCLUDES is a cross-agency initiative that will build on prior successes and run from FY 2016 to FY 2025.

¹<https://ncses.nsf.gov/pubs/nsb20197/demographic-attributes-of-s-e-degree-recipients>, Figure S2-7

²<https://ncses.nsf.gov/pubs/nsf19304/digest/introduction>

NSF INCLUDES Design and Development Launch Pilots (funded in FY 2016 and FY 2017), NSF INCLUDES Alliances (funded in FY 2018 and FY 2019), and an NSF INCLUDES Coordination Hub (funding commenced in FY 2018) formed the foundation for the NSF INCLUDES National Network. Opportunities to join the NSF INCLUDES National Network have been extended to other NSF-funded projects through on-ramps and language in more than ten Education and Human Resources and Research and Related Activities program solicitations inviting projects that align with the principles of NSF INCLUDES. Other organizations (*e.g.*, K–12 school districts, colleges and universities, professional organizations, government agencies, foundations, businesses and industries) will also be able to join the NSF INCLUDES National Network and support its goals. NSF INCLUDES Alliances will serve as test beds for designing, implementing, studying, and refining change models that are based on collective impact-style approaches. Thus, the NSF INCLUDES investment will provide valuable evaluation knowledge that will strengthen this initiative and contribute to NSF’s understanding of strategies for addressing the Nation’s most challenging diversity and inclusion issues.

The agency is developing evaluation metrics to gauge the success of its broadening participation programs and is incorporating Learning Agendas into its programs. For example, by building learning questions, activities, and products into INCLUDES, Learning Agendas help NSF bring together dedicated partners, find and scale approaches that work, and enhance STEM opportunities for all Americans.

Question 3. Why are we seeing so little change in participation by women in STEM fields?

Answer. The numbers of women and minorities who hold S&E degrees and are in the S&E workforce have increased but these groups remain underrepresented relative to their proportion in the U.S. population, given the rapid increase in the number of S&E jobs overall. Over the past two decades, the number of women with S&E degrees increased from 2.4 million to 58 million.³ In 2017, women constituted 29 percent of workers in S&E occupations—up from 23 percent in 1993. Among S&E degree holders, women represented 40 percent of employed individuals—up from 34 percent in 1993. These numbers mask an important distinction: participation by women varies among STEM fields. In social sciences, psychology, and biological sciences, women are overrepresented at most degree levels. However, in fields such as computer sciences and mathematics, engineering, and physical sciences, women represent only 27 percent, 16 percent, and 29 percent of the workforce⁴. Our work is cut out for us.

One factor that affects a woman’s education or career choice is the environment; it must be safe, welcoming, and inclusive for all, whether they are in a classroom, laboratory, office, or field station. In 2018, NSF published new conditions on awards designed to help foster research and educational environments that are free from harassment. Together with programs to familiarize and engage women in STEM fields at an earlier age, we expect to accelerate progress.

RESPONSE TO WRITTEN QUESTION SUBMITTED BY HON. EDWARD MARKEY TO
DIANE SOUVAIN, PH.D.

Question. In a budget priority memo released on August 30, 2019, Office of Science and Technology Policy Director Dr. Kelvin Droegemeier listed “protecting American research assets” as a cross-cutting priority action, widely considered to be a direct reference to cracking down on Federal scientists in the United States with foreign ties. Sixty scientific societies released a letter speaking out against the exclusion of foreign-born scientists and expressing the need to maintain national security without compromising an open, collaborative scientific environment. If enacted, what effect would these exclusionary priorities and approaches have on U.S. research and development leadership?

Answer. In his budget priority memo of August 30, 2019, Dr. Droegemeier stated that continuing our Nation’s success in American leadership in S&T will depend on “striking a balance between the openness of our research ecosystem and the protection of our ideas and research outcomes.” The November 19, 2019 Senate Homeland Security & Governmental Affairs Permanent Subcommittee on Oversight Committee hearing on “Securing the U.S. Research Enterprise from China’s Talent Recruitment Plans” sounded similar themes. Among the bipartisan observations were:

³ <https://ncses.nsf.gov/pubs/nsb20198/demographic-trends-of-the-s-e-workforce#women-in-the-s-e-workforce>

⁴ <https://ncses.nsf.gov/pubs/nsb20198/demographic-trends-of-the-s-e-workforce>

- The essential role of foreign talent in the U.S. S&E ecosystem
- The need to avoid profiling individuals based on their country of origin
- The need for U.S. S&T to play a key role in the international system of science
- The need to thoughtfully respond to the weaknesses in our system that the Chinese talent programs have exposed to ensure that we protect the American taxpayers' investments in S&E research.

The National Science Board's 2018 statement on Security and Science has also taken a similarly nuanced approach. Our statement reinforced that the pursuit of knowledge is a universal global enterprise, best undertaken through an open exchange of ideas and sharing of outcomes. At the same time, it also observed that there are sensitive areas of research in which national security considerations must prevail and called for dialog about any proposed changes to National Security Decision Directive-189. NSB has also stressed that U.S. universities and colleges must help promote scientific openness and integrity and safeguard information that impacts national security and economic competitiveness, including rigorously adhering to conflict of interest and conflict of commitment policies.

The Board's position is that if the U.S. continues to conduct its S&E enterprise consistent with the principled traditions that have yielded the success of the past 75 years, the benefits it realizes from nurturing a global community of similarly principled partners will far outweigh the losses it may suffer as a result of the openness it champions.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. GARY PETERS TO
DIANE SOUVAINE, PH.D.

Question 1. I was pleased that you mentioned during the hearing the National Science Board's visit to Michigan to see the collaboration between Macomb Community College, Wayne State University, and Detroit automakers, a collaboration funded by the NSF's Advanced Technological Education (ATE) Program. Training our young people in skilled jobs is vital to ensuring a strong workforce moving forward. However, according to the World Economic Forum, 65 percent of children today will work in jobs that currently don't exist. I have introduced legislation on this topic to ensure we are tracking these trends related to new technologies—like automation and AI—at the Department of Labor to inform our workforce development strategies. Can you share your thoughts on what tools we need to prepare students for the jobs of tomorrow?

Answer. Understanding the U.S. STEM workforce, and what is needed to ensure that this workforce is inclusive and leverages the ability and curiosity of all our people, has been an NSB priority for several years. Any successful strategy to prepare our students for the jobs of tomorrow must include a strong commitment to STEM education for all demographic groups and in all geographic regions, beginning in primary school and continuing across all levels of education. To prepare the Nation for the jobs of the future, we also need to address the misperceptions that STEM is just for scientists. We must improve STEM education here in the U.S., for example by giving everyone the opportunity for hands-on learning starting at an early age. We must provide all citizens with the skills necessary for the new economy, including critical thinking, problem-solving, creativity, communication, collaboration, and persistence. We must change the mind-set that learning occurs just in school or just for certain age groups; everyone must become a lifelong learner to adapt and thrive in a rapidly changing job market. Ensuring that all Americans are ready for the jobs of tomorrow is an ambitious goal, and one which requires the effort of many partners across government at all levels, working together with the private and non-profit sectors. Collectively, we must proceed with urgency and purpose to ensure that all our people are ready prepared.

Question 2. Dr. Souvaine emphasized the bipartisan nature of support for science and research. In 2016, thanks to the leadership of Sen. Gardner and then-Chairman Thune and Senator Nelson, we were able to pass the first major update to Federal research policy in more than a decade. One of the things our bill included was an emphasis on the need to encourage underrepresented people in the STEM fields. According to a study by Michigan State University Professor Lisa Cook, including more women and African Americans in the "initial stage of the process of innovation" could increase GDP by as much as 3.3 percent per capita. Can you speak about the importance of diversity in science and innovation?

Answer. The National Science Board believes that America's demographic diversity is a distinct competitive advantage. Research shows that diverse companies have better strategies, are more innovative, and win economically. Diversification of

our STEM-capable workforce must become a higher priority, as, according to the Census Bureau, by 2042 our country will be a majority-minority nation. The talents of minority groups in the U.S. may be our greatest untapped S&E resource. To be competitive in the 21st century global economy, which is increasingly driven by scientific and technological innovation, we must utilize the abilities and creativity of *all* our citizens, in all demographics and at all education levels, while continuing to welcome talent from across the globe. The *2020 Science and Engineering Indicators* report on the S&E Labor Force documents that the absolute numbers of women and minorities who hold S&E degrees and are in the S&E workforce have increased. These groups remain significantly underrepresented relative to their proportion in the U.S. population, however, given the rapid increase in the number of S&E jobs overall. Therefore, while we recognize that we have had demonstratable success at welcoming more women and underrepresented minorities into the S&E workforce, nonetheless, the country needs these participation rates to increase even more rapidly.

For its part, NSF has embraced this challenge through numerous programs, including one of its Big Ideas, Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (INCLUDES); the Established Program to Stimulate Competitive Research (EPSCoR); and the Advanced Technological Education (ATE) program. These and other programs operate within both the Directorate for Education and Human Resources (EHR) and the S&E research directorates.

Question 3. We included language in the American Innovation and Competitiveness Act to help root out unnecessary paperwork. Can you comment on the interactions you have with government funding agencies—and what, if any, unnecessary red tape still exists?

Answer. The language in AICA was very helpful in realizing recommendations from the National Academies of Science, Engineering, and Medicine,⁵ the Government Accountability Office,⁶ and the National Science Board.⁷ In response, OSTP has created a dedicated subcommittee of the National Science and Technology Council's (NSTC's) Joint Committee on the Research Environment (JCORE)—the subcommittee on Coordinating Administrative Requirements for Research. Having participated recently in the JCORE summit, I commend this effort to coordinate agency policies related to Federal grant processes, and in particular the efforts to engage and hear from the research community. I also note that members of NSF senior management co-chair all four of the JCORE subcommittees, actively engaging across funding agencies.

For our part, NSF and the Board are always seeking to balance effective grants management and the workload imposed on both universities and NSF program officers. Broadly speaking, we are pursuing improved use of persistent digital identifiers (such as ORCID) and research profiles to reduce the administrative work associated with applying for and reporting on Federal grants. NSF is working closely with NIH, for example, to use its SciENcv system to simplify reporting on qualifications and current and pending support.

Despite these efforts and those of Congress, however, preliminary reports from the Federal Demonstration Partnership (FDP) indicate that the time faculty spend on administrative activities rather than research is not decreasing. While frustrating, I believe this reflects two factors. First, some of the activities cited here, such as JCORE, have not yet had enough time to impact FDP's surveys. Second, it is important to recognize that red tape is not something that is cut once. While it would be tempting to point to the mythical Hydra, doing so trivializes an important consideration: many of the regulations deemed “red tape” are important for protecting public health, safety, and financial integrity. Nowhere is this more apparent right now than in efforts to assure research is free from improper foreign influence. Full disclosure of conflict of commitment, for example, is important for national security.

Regulations have and will continue to evolve as agencies improve. As this happens it is vital for all involved, including NSB, continuously to seek opportunities to minimize the burdens associated with administrative regulations. I believe that the level of awareness of the costs imposed on researchers and research institutions and the processes now in place for coordinating burden reduction activities are the best I've seen in over a decade on the Board.

⁵ National Academies report *Optimizing the Nation's Investment in Academic Research* (2016).

⁶ Government Accountability Office report *Federal Research Grants: Opportunities Remain for Agencies to Streamline Administrative Requirements* (2016).

⁷ National Science Board report *Reducing Investigators' Administrative Workload for Federally Funded Research* (2014).

Question 4. Michigan's University Research Corridor is #1 in the country for producing medicine and biological science graduates—this is a boon to our state on a number of fronts including research, employment, and quality of the work we produce in this field. Can you share any insights you have on research clusters and how they foster innovation and economic growth?

Answer. There has been a persistent link between research investment and economic growth. The National Center for Science and Engineering Statistics (NCSES) housed at NSF found a strong, positive correlation between business R&D spending in an area and the area's gross domestic product (GDP)⁸: areas with greater amounts of business R&D spending tend to have larger GDPs. The same situation applies to federally-supported research. An example of research clusters related to NSF is the Engineering Research Center Program (ERC). ERCs were initiated in 1985 as government-university-industry partnerships with an objective to advance U.S. industrial competitiveness. Since then, NSF has funded 67 ERCs across the United States. NSF funds each ERC at \$3 million to \$5 million per year for up to 10 years, during which time the centers build robust partnerships with industry, universities, and other government entities that can ideally sustain them upon graduation from NSF support. ERCs are credited with producing hundreds of millions of dollars of regional and national economic benefits.⁹

We call your attention to the testimony of Dr. David Shaw, Provost and Executive Vice President of Mississippi State University (MSU), who also spoke at this hearing. As Dr. Shaw stated, "Federal research investment has made a tremendous difference in our state. MSU won a National Science Foundation Engineering Research Center in 1990 focused on computational field simulation. We have many success stories that came from that ERC but none more important than how it was used to attract Nissan to the state of Mississippi. We leveraged the ERC to create a new Center for Advanced Vehicular Systems (CAVS) with a combination of basic research and industrial outreach to support the automotive industry in the state. In the past 10 years, CAVS has an impact of over \$2.9 billion in the state through jobs saved or created. Without that NSF investment, none of this would have been possible."

Question 5. Michigan blueberry growers produce about 100 million pounds of blueberries—in part because three of the most widely planted blueberry varieties were developed through agriculture research in our state—lengthening the harvesting season and increasing blueberry production. There was not much discussion in the testimony about agriculture research, but given how important is to our Nation's economy and to every American, can you comment on the importance of agriculture research to our food supply and public health?

Answer. Agricultural research is essential to our food supply and provides research-based information in nutrition that contributes to public health. The National Science Foundation (NSF) contributes to agricultural research by funding foundational research that can eventually lead to new crop varieties, more flavorful berries, more effective pollination and crop protection, and more efficient harvesting. NSF-supported, agriculture-relevant research spans the gamut from the fundamentals of plant and animal genomics, plant physiology, and biochemistry to machine learning and robotics.

NSF-supported research, in turns, lays a foundation for the basic and applied research programs supported by the U.S. Department of Agriculture's National Institute for Food and Agriculture (NIFA). NIFA's competitive grant programs directly support agricultural research at land grant universities like Michigan State University and other experimental stations. These programs support other types of foundational research but are also focused on research that translates research findings to the specific needs of producers and industry.

Question 6. Michigan is home to 15 research universities and is among the top 10 states in the country for R&D. One of the challenges that academia has had is the divide between town & gown and in communicating how the work that's done in the ivory tower makes a difference in people's everyday lives. Can you talk about what opportunities you see in improving this divide?

Answer. NSF funding provides opportunities to bridge this divide by helping researchers connect with their local communities and convey how science and engineering research improves people's lives, contributes to the economy, and supports national security. For example, Montcalm Community College in Sidney, MI has received NSF funds to host hands-on activities involving robots at high school and adult education schools to illustrate the rewards of a career in automation and man-

⁸<https://nsf.gov/statistics/2019/nsf19322/nsf19322.pdf>

⁹<https://www.nap.edu/catalog/24767/a-new-vision-for-center-based-engineering-research>

ufacturing.¹⁰ In another project, researchers at Central Michigan University will engage undergraduates from underrepresented groups in discussions on opportunities in biological sciences through a series of workshops and other activities that include shadowing museum professionals.¹¹

In addition, NSF publishes one-page factsheets for each state that describe how NSF funding supports discovery research that benefits people's lives, supports students, and develops the STEM workforce.¹² The National Science Board also publishes one-pagers for each state that provide a broad perspective on the S&E landscape, such as levels of R&D investment and the number of people employed in STEM fields.¹³

Question 7. The American Innovation and Competitiveness Act included the Crowdsourcing and Citizen Science Act [authored by Sen. Coons] to encourage broader input from the public. We've seen agencies start to use crowdsourcing as a way to harness increasingly prevalent data that can inform science and research endeavors. Can you speak to how your institution is leveraging or encouraging crowdsourcing to improve research?

Answer. NSF primarily supports crowdsourcing and citizen science via grants, contracts, cooperative agreements, and other funding mechanisms to non-Federal entities. NSF leverages and encourages crowdsourcing to improve research in three overlapping ways: (1) funding innovative research that includes crowdsourcing approaches, (2) funding research activities that increase our collective knowledge of how to apply crowdsourcing effectively to advance research—the science and practice of crowdsourcing, and (3) leveraging crowdsourcing as a mechanism to increase public participation in scientific research and learning of science, technology, engineering, and mathematics (STEM). NSF-funded crowdsourcing and citizen science programs even before the enactment of the American Innovation and Competitiveness Act and sees these programs as integral to broadening the participation of all Americans in our innovation ecosystem. Below are three examples of NSF-funded awards that use crowdsourcing.

Eyes on the future: optimizing science output for the next generation surveys with joint crowdsourced and automated classification techniques. Award Number: 1716602; Principal Investigator: Claudia Scarlata; Co-Principal Investigator: Lucy Fortson; Organization: University of Minnesota-Twin Cities; Start Date: 09/01/2017; Award Amount: \$654,657.00.

SCH: INT: Collaborative Research: Crowd in Action: Human-Centric Privacy-Preserving Data Analytics for Environmental Public Health Award Number: 1722791; Principal Investigator: Yuguang Fang; Organization: University of Florida; Start Date: 09/01/2017; Award Amount: \$413,000.00.

Collaborative Research: Improving Student Learning in Hydrology & Water Resources Engineering by Enabling the Development, Sharing and Interoperability of Active Learning Resources Award Number: 1726667; Principal Investigator: Daniel Ames; Co-Principal Investigator: James Nelson; Organization: Brigham Young University; Start Date: 09/01/2017; Award Amount: \$250,118.00.

In addition, with its 2026 Idea Machine, NSF asked researchers, the public, and other interested stakeholders to propose ideas that could help set the agenda in research and engineering. The competition is still ongoing, and a collection of video pitches can be found at <https://www.nsf.gov/cgi-bin/good-bye?https://nsf2026imgalery.skild.com/>

Question 8. Dr. Panchanathan referenced the National Science Foundation's "10 Big Ideas"—this is a way to help spark major leaps in research and innovation and get big ideas off the ground. Do you have thoughts on how we may be able to expand this approach to other fields or agencies?

Answer. The growth of big data and empirical modeling is transforming discovery science, much like calculus changed physics and computers changed engineering. These tools are letting researchers tackle questions that eluded us in a pre-big data world. In the near future, we will be able to run simulations and make predictions about complex systems, providing immensely powerful tools to policy makers and companies, and benefits to all Americans.

NSF developed its Big Ideas because it recognized the enormous potential of these new tools to push scientific advancements into heretofore unimaginable new frontiers. As the Nation's only Federal agency to fund basic research across all fields

¹⁰ Educating Robot Maintenance and Repair Technicians to Address Workforce Gaps in Automation and Skilled Trades. Award Number: 1902516.

¹¹ Engaging Underrepresented Populations in Biodiversity Sciences: A Series of Workshops for Undergraduate Students. Award Number: 1746715.

¹² https://nsf.gov/news/factsheets/michigan_factsheet.pdf

¹³ <https://www.nsf.gov/nsb/sei/one-pagers/Michigan-2018.pdf>

of science and STEM education, NSF tailored its Big Ideas to its mission. It is worth noting that many new tools, such as AI, are ripe for an explosion of public and private investment in part because NSF supported early-stage research years ago. Our approach does not necessarily translate to other research agencies with different missions and structures. However, other agencies are likewise championing initiatives in critical areas of science and technology to fuel our Nation's S&E enterprise, taking approaches that match their particular mission and role in the U.S. innovation ecosystem. Nonetheless, from what I have seen at NSF, major leaps in science and engineering can be achieved by embracing technology, organizational change, and the best ideas from the broader science and engineering community.

Collectively, NSF and other research agencies, including the Department of Energy's Office of Science, the Defense Advanced Research Projects Agency, the National Institute of Standards and Technology, the National Institutes of Health, and others are striving to seize upon the enormous opportunities to advance promising areas of science and technology and thus the prosperity, health, and security of humanity.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MARIA CANTWELL TO
DR. DAVID SHAW

Academic Espionage. There is growing concern that other nations, particularly China, have developed programs to expropriate United States research. While it is important to protect United States research and intellectual property, it is also important that associated policies and procedures do not stymie the free flow of scientific information, which is crucial to the research enterprise.

Question 1. Do you have a sense of how pervasive this problem is in on campus?

Answer. Mississippi State University has regular briefings from relevant Federal agencies on this topic, so we are aware of the issue and highly sensitive to it. We have implemented a number of safeguards at MSU to ensure that sensitive intellectual property is secure, while at the same time working to maintain academic freedom to continuously advance science and technology.

Question 2. How can the Federal government help universities and researchers protect federally funded research while maintaining the integrity of science in this country?

Answer. First and foremost, an ongoing and regular dialog with universities is crucial to maintain scientific leadership and integrity while protecting national interests. We at MSU schedule regular briefings for senior leadership, and consistently update training programs for faculty and students. Second, clear guidelines must continue to be developed so that universities are not left guessing about what Federal agencies require. We realize this continues to evolve, but we are also continually concerned about university accountability without clear guidance on this accountability.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. GARY PETERS TO
DR. DAVID SHAW

Question 1. Dr. Souvaine emphasized the bipartisan nature of support for science and research. In 2016, thanks to the leadership of Sen. Gardner and then-Chairman Thune and Senator Nelson, we were able to pass the first major update to Federal research policy in more than a decade. One of the things our bill included was an emphasis on the need to encourage underrepresented people in the STEM fields. According to a study by Michigan State University Professor Lisa Cook, including more women and African Americans in the "initial stage of the process of innovation" could increase GDP by as much as 3.3 percent per capita. Can you speak about the importance of diversity in science and innovation?

Answer. Expanding diversity in science is critical for our future success as a nation. It is imperative if we are to "lift all boats" that all sectors of our society are engaged in science and technology. We must focus on being a nation of haves, not haves and have-nots. That is why programs such as the Established Program to Stimulate Competitive Research (EPSCoR) at NSF, and similar programs at other agencies, are placing focus on both geographic diversity as well as ethnic and gender diversity. Other programs important to promoting diversity at the early stages of innovation include the NSF I-Corp program. I-Corp nurtures and supports innovation and entrepreneurship among young scientist and engineers. At MSU we are very proud of our Center for Entrepreneurship. With several successful startups, including startups led by minority students and women, this program now serves 100s of students each year. This program is open to all students, no matter their dis-

cipline, to help them turn their incredible, enthusiastic ideas into startup businesses. With minorities and women underrepresented in science and engineering majors, having university entrepreneurship programs open to all students, no matter their major, expands opportunities to underrepresented groups in innovation and entrepreneurship.

Question 2. We included language in the American Innovation and Competitiveness Act to help root out unnecessary paperwork. Can you comment on the interactions you have with government funding agencies—and what, if any, unnecessary red tape still exists?

Answer. This language has certainly been beneficial to help reduce the bureaucracy associated with research grants management. It is certainly a laudable goal to allow researchers to spend more time on research and innovation, rather than dealing with bureaucratic paperwork. However, while some red tape has been reduced or eliminated, concerns (some legitimate) in areas such as research ethics and compliance have actually increased the overall paperwork that researchers face.

Question 3. Michigan's University Research Corridor is #1 in the country for producing medicine and biological science graduates—this is a boon to our state on a number of fronts including research, employment, and quality of the work we produce in this field. Can you share any insights you have on research clusters and how they foster innovation and economic growth?

Answer. Many of the most successful innovation centers in the Nation have come about because of the cluster concept you mention. On a scale much smaller than your example in Michigan, the Thad Cochran Research, Technology and Economic Development Park adjacent to the MSU campus is doing just that. We have clustered several of the relevant university research centers with our business incubator and corporate facilities. The research park is full to overflowing, and we recently expanded into a downtown Starkville location because of this growth. Many of our land grant universities are located in rural areas. Finding ways to foster strong connections between research clusters born of our university systems and rural city centers is critical to economic development.

Question 4. Michigan blueberry growers produce about 100 million pounds of blueberries—in part because three of the most widely planted blueberry varieties were developed through agriculture research in our state—lengthening the harvesting season and increasing blueberry production. There was not much discussion in the testimony about agriculture research, but given how important is to our Nation's economy and to every American, can you comment on the importance of agriculture research to our food supply and public health?

Answer. Thank you for this question, as agricultural research is highly meaningful to our state, and our university. MSU currently ranks ninth in the Nation in agricultural research, and places tremendous emphasis on the partnership we have with the USDA Agricultural Research Service. Innovations in agricultural research has improved yields, enhanced drought resistance, reduced pesticide usage while improving pest management, and provided more nutritious food products to our Nation and world. Agriculture research is essential to natural resource management and sustainability, including water, forests, soils, and energy. Agricultural research is also addressing some of the most pressing health issues we have, ranging from healthier food products to better understanding of the sociological dimensions of health disparities.

Question 5. Michigan is home to 15 research universities and is among the top 10 states in the country for R&D. One of the challenges that academia has had is the divide between town & gown and in communicating how the work that's done in the ivory tower makes a difference in people's everyday lives. Can you talk about what opportunities you see in improving this divide?

Answer. The university community has come to recognize this issue, and recently the Association of Public and Land-Grant Universities published a report entitled Public Impact Research: Engaged Universities Making a Difference (see <https://www.aplu.org/projects-and-initiatives/research-science-and-technology/public-impact-research.html/index.html>). At MSU, we continually focus on translation of our research into language that is easily understood and interpreted by the public. This past year we hosted the Alan Alda Center for Communicating Science from Stoneybrook University in a two-day workshop for our faculty and administration.

Question 6. The American Innovation and Competitiveness Act included the Crowdsourcing and Citizen Science Act [authored by Sen. Coons] to encourage broader input from the public. We've seen agencies start to use crowdsourcing as a way to harness increasingly prevalent data that can inform science and research endeavors. Can you speak to how your institution is leveraging or encouraging crowdsourcing to improve research?

Answer. MSU has encouraged novel crowdsourcing approaches in both our research programs and our entrepreneurship center's activities. We have seen several startups developed by our students and faculty based on the concepts of crowdsourcing. We have also conducted innovative research that utilizes social media for both cybersecurity and predictive analytics capabilities.

Question 7. Dr. Panchanathan referenced the National Science Foundation's "10 Big Ideas"—this is a way to help spark major leaps in research and innovation and get big ideas off the ground. Do you have thoughts on how we may be able to expand this approach to other fields or agencies?

Answer. The concept of Grand Challenges or Big Ideas is extraordinarily useful in stimulating trans-disciplinary approaches to scientific discovery. The most pressing issues facing our society today—e.g. water quantity and availability, health disparity, food security—require all of the sciences to work together if we are to adequately address these problems. Physical, biological, and social sciences are unaccustomed to working together, and barriers to these collaborations are as fundamental as different vocabularies associated with these disciplines. Big Ideas are an effective means of rallying disparate disciplines to come together and overcome the hurdles inherent with the institutional and academic barriers that typically exist. Society is not short on Grand Challenges, and other agencies should be expected to define these challenges and design programs that cross their own institutional barriers to develop cross-program collaborative efforts. This requires a fundamental rethink for the agencies as well, since ownership of specific programs within line offices and directorates is threatened when the topic crosses multiple lines. It is also difficult for reviewers, since each bring their own biases toward their own and other disciplines. Therefore, agencies must be required to develop specific plans to overcome these barriers, using lessons that have been learned from the NSF experience, to successfully identify research projects that can be examples of trans-disciplinary approaches to problem-solving.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MARIA CANTWELL TO
SETHURAMAN (PANCH) PANCHANATHAN, PH.D.

Academic Espionage. There is growing concern that other nations, particularly China, have developed programs to expropriate United States research. While it is important to protect United States research and intellectual property, it is also important that associated policies and procedures do not stymie the free flow of scientific information, which is crucial to the research enterprise.

Question 1. Do you have a sense of how pervasive this problem is in on campus?

Answer. Despite the fact that academic espionage is of critical importance to major research universities—particularly those of us with a substantial international student population—our research concurs with most national estimates that a very high percentage of those collaborating with ASU or studying at ASU are doing so with proper intent. That being said, we have numerous safeguards in place to protect against academic espionage while still encouraging both fundamental and applied research in collaborative fashion. Some of ASU's institutional oversight includes:

- Hosting outreach from Homeland Security, Customs, Immigrations and Border Enforcement to provide outreach and guidance related to foreign influence for research operations staff, research administrative staff directly supporting faculty, and International Student Scholars.
- Inquiries from Federal Agencies related to Foreign Influences are routed to the Office for Research and Sponsored Project Administration (ORSPA) for institution investigation, review and response.
- Foreign research gifts are not routed without Sponsor review—the ASU Foundation routes all grants and gifts from foreign sponsors through ORSPA. This assures that we do not provide any sensitive material, including IP, to China or any other country of concern that is not in the public domain.
- Foreign sponsors and subrecipients are vetted for restricted party screening and flags restriction in ERA to ensure compliance, and a risk assessment is performed in advance of any contract execution.
- We monitor foreign travel to China and other countries of concern for investigators who are federally funded, or whose work is defense or export-related.
- We have implemented a systematic audit of foreign travel to countries of concern against disclosed financial interest to monitor for compliance and resolve and correct any discrepancies.

Question 2. How can the Federal government help universities and researchers protect federally funded research while maintaining the integrity of science in this country?

Answer. Research has many threads; basic, translational and mission-focused. In general, academic researchers are mostly engaged in curiosity-driven explorations. While some areas of research, such as cyber, are sensitive, most basic research explorations should be disseminated widely, in order to ensure rapid progress through fundamental discoveries. Promoting global collaborations around non-sensitive and basic areas of research are mutually beneficial and important. Research around sensitive themes can be managed carefully by strong policies and procedures, which in turn, will ensure competitiveness and national security. The diverse nature of research topics can also be effectively managed by training researchers in the art of ethical behavior and sound judgment.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. GARY PETERS TO
SETHURAMAN (PANCH) PANCHANATHAN, PH.D.

Question 1. Dr. Souvaine emphasized the bipartisan nature of support for science and research. In 2016, thanks to the leadership of Sen. Gardner and then-Chairman Thune and Senator Nelson, we were able to pass the first major update to Federal research policy in more than a decade. One of the things our bill included was an emphasis on the need to encourage underrepresented people in the STEM fields. According to a study by Michigan State University Professor Lisa Cook, including more women and African Americans in the “initial stage of the process of innovation” could increase GDP by as much as 3.3 percent per capita. Can you speak about the importance of diversity in science and innovation?

Answer. Diversity in STEM is critical to ensuring innovation and competitiveness. Innovative mindsets inherently demand ideas that are representative of the broad demographic of our society. Jobs of the future will require STEM expertise that transcends gender, race and culture. An inclusive scientific environment will guarantee positive and beneficial outcomes. It is important that we focus on increasing women and minority representation in STEM to ensure a robust science & engineering workforce. In addition, there are an increasing number of jobs that require STEM skills but do not require a bachelor's degree. The racial/ethnic demographics of this “skilled technical workforce” closely mirror that of the U.S. as a whole, offering a pathway into the science & engineering workforce for a diverse population as well as excellent career opportunities in their own right.

Question 2. We included language in the American Innovation and Competitiveness Act to help root out unnecessary paperwork. Can you comment on the interactions you have with government funding agencies—and what, if any, unnecessary red tape still exists?

Answer. Researcher burden results when multiple government agencies have different submission and compliance requirements; the result is that researchers spend a significant amount of time that could be spent on scientific discovery weighed down by administrative burdens. Creating seamless and uniform requirements and processes, where possible, will greatly benefit the conduct of research.

Question 3. Michigan's University Research Corridor is #1 in the country for producing medicine and biological science graduates—this is a boon to our state on a number of fronts including research, employment, and quality of the work we produce in this field. Can you share any insights you have on research clusters and how they foster innovation and economic growth?

Answer. Research clusters facilitate collaboration among different disciplines focused on solving grand challenge problems that have economic and societal benefits. The transdisciplinary fusion of ideas is inherently innovative, and has the potential for significant technology transfer outcomes. Research clusters also promote an environment of information and resource sharing that is pivotal to advance knowledge. When researchers, academics, non-profits and corporates work in a team, it facilitates economic growth, and encourages an entrepreneurial mindset.

Question 4. Michigan blueberry growers produce about 100 million pounds of blueberries—in part because three of the most widely planted blueberry varieties were developed through agriculture research in our state—lengthening the harvesting season and increasing blueberry production. There was not much discussion in the testimony about agriculture research, but given how important is to our Nation's economy and to every American, can you comment on the importance of agriculture research to our food supply and public health?

Answer. Agricultural research is critical to ensuring access to safe, reliable, sustainable food and water sources for all Americans. As the world's population continues to expand, agricultural research plays a role in ensuring a safe, available food supply for the U.S., as well as bolstering U.S. crop exports, which has a direct correlation to our Nation's economic prosperity. Exploration of and research into new growing and harvesting techniques, animal husbandry, food storage and preservation, mitigation of crop damage due to weather and pests, and drought-tolerant farming are all key areas of agricultural research.

Question 5. Michigan is home to 15 research universities and is among the top 10 states in the country for R&D. One of the challenges that academia has had is the divide between town & gown and in communicating how the work that's done in the ivory tower makes a difference in people's everyday lives. Can you talk about what opportunities you see in improving this divide?

Answer. Being embedded in the communities in which universities operate is a key element in resolving this divide. It is incumbent upon university leadership to ensure students, faculty and staff are good citizens of the university towns in which they reside. Like Michigan universities, ASU is deeply committed to a strong town & gown partnership. We work closely with our cities in the metropolitan Phoenix area, the county, and the state to ensure our contribution to robust economic development. Part of ASU's charter speaks to this effort: "*ASU is a comprehensive public research university, measured not by whom it excludes, but by whom it includes and how they succeed; advancing research and discovery of public value; and assuming fundamental responsibility for the economic, social, cultural, and overall health of the communities it serves.*"

Question 6. The American Innovation and Competitiveness Act included the Crowdsourcing and Citizen Science Act [authored by Sen. Coons] to encourage broader input from the public. We've seen agencies start to use crowdsourcing as a way to harness increasingly prevalent data that can inform science and research endeavors. Can you speak to how your institution is leveraging or encouraging crowdsourcing to improve research?

Answer. We have several groups at Arizona State University that harness the power of crowdsourcing, bringing together data sets for distribution to the community. It's not restricted to any one discipline or audience. Open datasets are accessible to all to allow for many different minds to be engaged in solving problems. This approach lets us operate at scale—the more minds reviewing projects, the greater our research potential. We also utilize a form of crowdsourcing internally, called a Spark Session. Sessions bring together staff, decision-makers, subject matter experts and students to examine a specific issue. The group develops solutions and selects viable options, as well as plans for implementation.

Question 7. Dr. Panchanathan referenced the National Science Foundation's "10 Big Ideas"—this is a way to help spark major leaps in research and innovation and get big ideas off the ground. Do you have thoughts on how we may be able to expand this approach to other fields or agencies?

Answer. The NSF's 10 Big Ideas is a great platform for bringing together researchers from different disciplines focused on solving grand challenge problems that have a direct impact on scaling discovery, solutions, tech transfer and entrepreneurship. This approach needs to be scaled across all agencies and through inter-agency partnerships and corporate collaborations. For example, the problem of ensuring potable water across the Nation requires the bringing together of multidisciplinary scholars and practitioners from academia, industry, government and non-profits toward finding sustainable solutions.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MARIA CANTWELL TO
REBECCA M. BLANK

Academic Espionage. There is growing concern that other nations, particularly China, have developed programs to expropriate United States research. While it is important to protect United States research and intellectual property, it is also important that associated policies and procedures do not stymie the free flow of scientific information, which is crucial to the research enterprise.

Question 1. Do you have a sense of how pervasive this problem is on campus?

Answer. We do not have evidence of major security problems related to research and intellectual property on our campus. However, we know the potential exists for problems—particularly in interactions with China, Russia, North Korea, and Iran.

As you point out, these issues require a balancing act. We need to address them in a manner consistent with our culture of openness and collaboration.

UW has taken a number of steps to do this. For example:

We have a Security Concerns Group with membership from faculty and the administration, as well as representatives from key campus offices such as legal affairs, research compliance, export control, and information technology. The group works to develop policies, procedures, and strategies related to our activities that involve foreign entities.

We also have expanded the questions we ask on the report that all faculty and academic staff are required to submit annually to disclose outside activities. Faculty and staff are now required to report a much broader set of interactions with foreign entities. Federal agencies including NIH, NSF, DOD, and DOE also now require enhanced reporting—and part of our work is to ensure that our researchers are up to date on these changing requirements.

Stronger security may protect intellectual property, but we must be on guard against an overly aggressive approach that can have a chilling effect on important research and discourage top scholars from coming to the U.S.

Question 2. How can the Federal Government help universities and researchers protect federally funded research while maintaining the integrity of science in this country?

Answer. Safeguarding against academic espionage requires, first and foremost, excellent communication between universities and Federal agencies (not just Federal funding agencies, but national security agencies such as the FBI).

It is critical to have processes for policymaking and decision making that are as transparent as possible. Universities need access to information about cases involving NIH, NSF or other agencies. It is helpful for us to know, for example, whether appropriate rules were followed, how the misconduct was discovered, and other details that could be useful in improving our own systems.

Universities are also looking for uniformity in the way Federal agencies define research misconduct, and consistency in the agencies' responses to allegations of misconduct. Another issue in the handling of some research misconduct cases relates to delays in reaching the inquiry and investigation stages.

Finally, it is important that Federal agencies maintain a firm commitment to supporting the principles of academic freedom and understanding the importance of academic collaboration with a global pool of talent.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. GARY PETERS TO
REBECCA M. BLANK

Question 1. We appreciated your decade-long tenure at the Ford School at the University of Michigan—particularly your creation of the National Poverty Center—which does tremendous multidisciplinary work. Can you share the history of the National Poverty Center and some of your insights on the cross disciplinary approach that they employ?

Answer. While I was dean, we sought—and received—funding from the Federal Government to start the National Poverty Center (NPC) at the Ford School at the University of Michigan (UM). While the Federal Government no longer provides core funding for the NPC, it has been successful at raising funds from multiple foundations for its projects and has received support from UM as well.

One reason this center worked well at the Ford School was the interdisciplinary nature of that school. It included faculty trained in economics, political science, sociology, and other areas. UM also has a strong tradition of interdisciplinary research and collaboration within the social sciences. While I was dean, we created an interdisciplinary Ph.D. program at the Ford School, which admits students to a joint degree program between the School and one of these three social science departments. The group that worked on this project, together with the collaborative social science tradition at UM, made the National Poverty Center almost immediately successful in involving in faculty and students in its seminars and research programs.

Like many areas of scientific inquiry, the study of poverty is often more revealing when questions are looked at through multiple disciplinary lenses. The employment challenges facing poor families interact with government programs and politics, and also interact with the family dynamic and demographic dynamics. The National Poverty Center continues to thrive because of the important research projects it has helped sponsor and the strong group of faculty who are involved.

I would also note that the University of Wisconsin—Madison is home to the first federally funded poverty center in the U.S., the Institute for Research on Poverty (IRP). IRP has received core Federal funding for over 50 years and is currently the only national poverty research center funded by HHS.

Like UM, UW has a strong collaborative tradition in the social sciences. Our IRP has sponsored important research on poverty throughout its 50 years, involving faculty from the social sciences, and including psychology, public health, and other areas.

Question 2. In your testimony, you cited a paper titled the *Economic Evaluation of the War on Cancer*—noting that research investments also create economic benefits from improved treatments or better products and services. Can you expound on the economic point you are making here about the sometimes hidden value of basic research?

Answer. If you look at the sources of economic growth over the past 40 years, about one-third is due to growth in the number of people or in the skills of the workforce. The other two-thirds is driven by innovation. This includes new products as well as new processes that allow companies to operate more efficiently.

Innovation comes out of the discovery process academics call research. While applied research focuses on solving a specific problem, basic research aims to expand knowledge in a given field. Basic research is often underappreciated since its contribution is less easy to understand in the short run. Typically, it's highly theoretical without any immediate or obvious application. But today's basic research is the basis for tomorrow's innovation in industry.

Basic research done in the 1950s and 1960s in engineering, electronics, early computers, and materials science led to the explosion of new technologies that have transformed our world, including personal computers, mobile phones, and GPS.

Basic biological research from past decades is now leading to a revolution in medicine, with individually targeted treatments based on personal genomic information.

The majority of basic research is conducted at universities—and the Federal Government funds a large share of it. Public support for this research is necessary, as very few private companies are investing in basic and more theoretical research.

Question 3. You noted the importance of translational research—helping bridge fundamental discoveries to a point where they can be applied and utilized in products and services. Can you talk about this divide—and the importance of investments in translational research?

Answer. While basic research forms the foundation of all future discoveries, it's also vital that we find ways to apply this knowledge in practical ways. There needs to be a continuum of investment from foundational to applied lines of investigation.

For example, 20 years ago, UW—Madison researchers isolated human embryonic stem cells. Today, the use of stem cells in research is central to developing new treatments for a growing number of diseases.

These applications are possible because of decades of further investment and investigation in what began as a basic discovery. Bipartisan support for this work was critical. At the same time, continued investment in basic research allowed our scientists to develop induced pluripotent stem cells, which are derived from skin cells and provide new opportunities for personalized medicine.

Another example of how translational research grows from basic research comes from quantum computing. For decades, Federal funding has supported university research that advanced our knowledge of quantum physics. This research has already led to many new technologies, including the MRIs in our hospitals. We are now rapidly progressing toward practical quantum computers, which are important to national cybersecurity and promise a wealth of other useful applications.

UW—Madison is a leader in this emerging field, and we are training the next generation of quantum computer scientists who will enter a rapidly growing job market that didn't exist a decade ago.

Question 4. Dr. Souvaine emphasized the bipartisan nature of support for science and research. In 2016, thanks to the leadership of Sen. Gardner and then-Chairman Thune and Senator Nelson, we were able to pass the first major update to Federal research policy in more than a decade. One of the things our bill included was an emphasis on the need to encourage underrepresented people in the STEM fields. According to a study by Michigan State University Professor Lisa Cook, including more women and African Americans in the “initial stage of the process of innovation” could increase GDP by as much as 3.3 percent per capita. Can you speak about the importance of diversity in science and innovation?

Answer. The research on this is clear. Diversity drives creativity and innovation in problem solving and design, and a lack of diversity can lead to design oversights that may have serious consequences. The classic example is the first generation of automobile airbags, which gave optimal protection for a person the size of an average adult male but were lethal for smaller drivers. Diverse perspectives are also important to identifying research questions and innovative areas for future funding and investigation.

U.S. universities play a critical role in STEM innovation and carry the responsibility for educating the next generation of innovators. However, faculty and students at U.S. universities currently fall far short of reflecting national gender demographics in most STEM fields and racial or ethnic demographics in every STEM field. Additionally, losses incurred at each level of career progression are disproportionately high for underrepresented populations.

To take full advantage of opportunities for future STEM innovation, it is imperative that we take full advantage of our talent pool. That means universities must continue efforts to eliminate disparities in our student and faculty STEM populations. Accelerating the pace of change requires efforts directed at multiple groups: faculty, postdoctoral researchers, graduate students, undergraduate students and pre-college students.

At UW—Madison, one of these efforts is the Women in Science and Engineering Leadership Institute. The institute leads training for faculty search committees, training on unconscious bias, and workshops to support department chairs in improving workplace climate.

Question 5. We included language in the American Innovation and Competitiveness Act to help root out unnecessary paperwork. Can you comment on the interactions you have with government funding agencies—and what, if any, unnecessary red tape still exists?

Answer. The 2018 Federal Demonstration Partnership Faculty Workload Survey reveals that, nationally, on average, principal investigators on Federal grants and contracts spent 44.3 percent of their time on administrative tasks related to these grants in 2017 (UW—Madison was comparable at 43.1 percent). The national average reflects a 2 percent increase over what was reported in the 2012 survey.

The most time-consuming responsibilities are report preparation, project finances, and activities related to compliance with rules on animal subjects, human subjects, laboratory safety, and national security.

It's important to note that Federal regulations help to ensure research integrity and increase access to research data and results, and also protect human and animal subjects in research. But excessive regulation creates unnecessary costs and slows (in some cases stops) valuable research.

Congress has worked to reduce the administrative burden, but more action is needed at the Federal level. For example:

- Standardizing requirements across agencies
- Standardizing grant application forms
- Giving universities, in some cases, more flexibility to assess and manage risks for certain requirements
- Addressing ineffective and outdated regulations that do not improve animal welfare
- Developing a standard set of assurances for grant applicants and recipients to eliminate the need to make multiple assurances on a grant-by-grant basis and eliminate the need for funding agencies to review assurances on each grant application. The Federal Government receives over 200,000 grant applications every year that require the completion of assurances.

We appreciate your continued work in this important area.

More on the results of the 2018 Federal Demonstration Partnership Faculty Workload Survey is available here: <http://thefdp.org/default/assets/File/Presentations/FDP%20FWS3%20Results%20Plenary%20Jan19%20fnl.pdf>

Question 6. Michigan's University Research Corridor is #1 in the country for producing medicine and biological science graduates—this is a boon to our state on a number of fronts including research, employment, and quality of the work we produce in this field. Can you share any insights you have on research clusters and how they foster innovation and economic growth?

Answer. Research clusters typically include 3–4 faculty from a variety of academic disciplines who work together on a research project but come at it from different angles. Clusters are ideal for addressing complex problems that sit at the juncture of multiple disciplines.

Freshwater sustainability is a great example. Ensuring a sufficient, reliable, and safe water supply is one of the top global resource challenges of the 21st century. It's a challenge that will require not only water scientists but also engineers, agricultural economists, public health experts, political scientists, and many others.

Research clusters are focused on addressing specific problems, and often result in discoveries that translate into new products.

For example, a neuroscience cluster created at UW—Madison in 2000 has moved us closer to better treatments for Parkinson’s disease and spinal cord injuries, and it’s produced 17 new patents, a start-up company, and \$33 million in grants and donor gifts that keep the cycle of discovery going strong.

Question 7. Michigan blueberry growers produce about 100 million pounds of blueberries—in part because three of the most widely planted blueberry varieties were developed through agriculture research in our state—lengthening the harvesting season and increasing blueberry production. There was not much discussion in the testimony about agriculture research, but given how important is to our Nation’s economy and to every American, can you comment on the importance of agriculture research to our food supply and public health?

Answer. Michigan blueberries are a favorite here in Wisconsin. They are especially delicious baked into muffins alongside Wisconsin cranberries!

As a public land-grant university, UW—Madison was created with a mission to advance agriculture—which means we make deep investments in research, education, and outreach related to developing nutritious and sustainable foods, improving food safety, and helping farmers and producers to thrive.

University researchers do the important work of developing improved breeds of livestock and hardier crops adapted to each state’s needs and to changes in climate. We also do work that is critical to securing the food supply and protecting farmers’ investments in their fields.

One example is the Wisconsin Seed Potato Certification program. This program ensures that the seed potatoes from which potato crops are grown are free from infection, which protects our Nation’s sixth-largest crop from harvest-ruining diseases. UW—Madison certifies 200 million pounds of seed potatoes each year, which translates into 90,000 acres for commercial production in Wisconsin and around the country.

You also asked how agricultural research can protect public health. Many diseases are shared between livestock and their human caretakers, and agricultural and animal scientists cooperate to maintain the health of both populations. For example, our School of Veterinary Medicine works with our School of Medicine and Public Health to test and vaccinate farm workers and dairy cows for tuberculosis, which can spread easily on farms. Early detection is critical to public health and safeguards the livelihood of our dairy farmers.

Question 8. Michigan is home to 15 research universities and is among the top 10 states in the country for R&D. One of the challenges that academia has had is the divide between town & gown and in communicating how the work that’s done in the ivory tower makes a difference in people’s everyday lives. Can you talk about what opportunities you see in improving this divide?

Answer. Part of our mission as a public university is to share knowledge and discoveries outside the borders of the campus to strengthen communities and make people’s lives better. But as you point out, we haven’t always been very good at telling this story.

Like many public universities, UW—Madison has a robust communications program that helps to raise awareness of our work and its statewide impact, but building the relationships that allow us to bridge campus/state divides requires a dedicated local presence. For that, our most powerful resource is the Cooperative Extension Service. Extension educators live in the communities they serve, so they’re not just visitors from the university—they’re working alongside their neighbors to identify local problems and help direct university resources toward finding solutions.

UW—Madison’s Division of Extension has educators in every Wisconsin county and in three tribal nations.

Our Extension program recently has been reintegrated into our flagship campus after existing for about 50 years as a separate entity. This restructuring has opened up new opportunities to connect the practical expertise of Extension educators with the academic expertise of university researchers. We are intentionally connecting the two groups to work on issues that have a major statewide impact, including water quality, opioid addiction, and the opportunity gap in education.

Question 9. The American Innovation and Competitiveness Act included the Crowdsourcing and Citizen Science Act [authored by Sen. Coons] to encourage broader input from the public. We’ve seen agencies start to use crowdsourcing as a way to harness increasingly prevalent data that can inform science and research endeavors. Can you speak to how your institution is leveraging or encouraging crowdsourcing to improve research?

Answer. Crowdsourcing is a valuable tool that allows researchers to overcome the logistical constraints of gathering data over geographically large areas or over long

periods of time. It is also a valuable tool for building public engagement with, and appreciation for, science.

UW—Madison is involved in many research projects that have a crowdsourcing component. They typically involve research in three broad areas: the environment, health, and climate.

Our environmental researchers are crowdsourcing data on urban foxes and coyotes, butterflies, bumblebees and honeybees, ticks, birds, forest fungi, and several invasive plant and animal species, to name just a few. The resulting data will inform decision making in conservation, disease prevention, and crop production.

Our health researchers are participating in a global program called Tiny Earth that is collecting soil specimens from around the world and testing them for novel microorganisms that could lead to new antibiotics. And UW—Madison is a partner in All of Us, an initiative of NIH to speed up medical breakthroughs by crowdsourcing health data.

Our climate scientists are crowdsourcing data on snow depth and density, water quality, and crop yields to better predict and respond to climate change.

Of course, crowdsourcing is not only about quantity. We need data that is high-quality. As we work to recruit more citizen scientists, we are also collecting and sharing best practices on volunteer engagement, data management, and program evaluation with our faculty and staff.

Question 10. Dr. Panchanathan referenced the National Science Foundation’s “10 Big Ideas”—this is a way to help spark major leaps in research and innovation and get big ideas off the ground. Do you have thoughts on how we may be able to expand this approach to other fields or agencies?

Answer. Ten Big Ideas proposes to make a significant financial investment (\$30 million in each Big Idea) to identify and support emerging opportunities for U.S. leadership in areas that are important to the Nation’s future.

On a smaller scale, UW—Madison has had success with a program called UW2020 that provides seed money for research projects that have the potential to fundamentally transform a field of study but need further development before they can compete for Federal funding. UW2020 might be a model for other universities as it seeks to fund research projects.

The NSF 10 Big Ideas model could also be adapted by other Federal agencies to focus on their areas of interest. For example, in meeting the goals of its strategic plan, NIH could issue 10 Big Ideas to support emerging health-related projects in precision medicine to improve cancer outcomes, create a universal flu vaccine, promote health and prevent illness in populations that are historically underserved, or revolutionize drug-screening tests.

