A REVIEW OF THE NATIONAL SCIENCE FOUNDATION FISCAL YEAR 2020 BUDGET REQUEST

HEARING

BEFORE THE

SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY

COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY

HOUSE OF REPRESENTATIVES

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C O N T E N T S

May 8, 2019

A REVIEW OF THE NATIONAL SCIENCE FOUNDATION FISCAL YEAR 2020 BUDGET REQUEST

WEDNESDAY, MAY 8, 2019

HOUSE OF REPRESENTATIVES,
SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, D.C.

The Subcommittee met, pursuant to notice, at 10:03 a.m., in room 2318 of the Rayburn House Office Building, Hon. Haley Stevens [Chairwoman of the Subcommittee] presiding.

U.S. HOUSE OF REPRESENTATIVES
SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
HEARING CHARTER

A Review of the National Science Foundation FY 2020 Budget Request

Wednesday, May 8, 2019
10:00 am – 12:00 pm
2318 Rayburn House Office Building

PURPOSE

On Wednesday, May 8, 2019, the Subcommittee on Research and Technology of the Committee on Science, Space, and Technology will hold a hearing to review the Administration's fiscal year 2020 budget request for the National Science Foundation and related policy and management issues.

WITNESSES

- **Dr. France Córdova**, Director, National Science Foundation
- **Dr. Diane Souvaine**, Chair, National Science Board

BACKGROUND

The National Science Foundation (NSF or the Foundation) was established by Congress in 1950 as an independent federal agency with a mission "to promote the progress of science; to advance the national health, prosperity and welfare; to secure the national defense; and for other purposes."[1]

Governance – As an independent agency, the Foundation does not fall within a cabinet department. The agency's activities are governed jointly by the Foundation Director and the National Science Board (NSB or the Board). The Director is appointed to a six-year term by the President and confirmed by the Senate.[2] The current NSF Director, Dr. France Córdova, was appointed by President Obama in 2014. Her term is set to expire in March 2020.[3]

The Board consists of 24 members appointed to six-year terms by the President.[4] The NSB performs two primary functions: (1) provide policy direction to NSF, including approval of the annual budget submission to the Office of Management and Budget (OMB) and new major programs and awards, and (2) serve as an external advisory body to Congress and the President on policy issues pertaining to science and engineering and STEM education. The Board also publishes a biennial report on indicators of the state of science and engineering in the United

[1] National Science Foundation Act of 1950, http://uscode.house.gov/statviewer.htm?volume=64&page=149
[2] The Deputy Director position is similarly appointed by the President, but this position has been vacant since 2014.
[3] NSF, "France A. Córdova sworn in as NSF director," https://www.nsf.gov/news/news_summ.jsp?cntn_id=130931
[4] NSB appointments are staggered so that every two years one-third of the Board is appointed.

States.[5] The Board Chair and Vice Chair are elected to two-year terms by the Board membership. The current Chair, Dr. Diane Souvaine, was elected in 2018. Her term will expire in May 2020.[6,7]

Research and Education – NSF supports fundamental non-biomedical research and education across all fields of science and engineering. For many research disciplines, including computer science, biology, environmental science, and social science, NSF is the primary source of Federal funding.

Research and education activities are managed through six research directorates under the Research and Related Activities Account – Biological Sciences (BIO), Computer and Information Science and Engineering (CISE), Engineering (ENG), Geosciences (GEO), Mathematical and Physical Sciences (MPS), Social, Behavioral and Economic Sciences (SBE) – and the Education and Human Resources (EHR) directorate under its own account. Each directorate is headed by an assistant director and further subdivided into divisions. Interdisciplinary research and agency-wide initiatives are funded through the Office of Integrative Activities, which is housed in the Office of the Director.

To support research and education activities, NSF typically enters into a grant agreement[8] with universities or other non-profit organizations. In FY 2018, NSF received more than 40,300 research grant proposals and made about 9,000 new awards to colleges, universities, and other institutions across all 50 states. Across the agency, 22 percent of proposals were selected for grant awards in FY 2018. The average award size that year was $182,100 over 3 years. Activities funded by NSF in FY 2018 involved an estimated 50,000 researchers and postdoctoral associates, 80,000 graduate and undergraduate students, and 242,000 K-12 teachers and students.[9]

Facilities – In addition to research grants, NSF funds advanced equipment and facilities that are critical to the agency's mission but too costly for an individual or small group of investigators to afford. NSF enters into cooperative agreements[10] with universities or other non-profit organizations for the construction and management of major facilities. Large equipment and facility projects include multi-user facilities, such as astronomical observatories and ocean

[5] The most recent Indicators report was released in January 2018 and can be found here: https://www.nsf.gov/statistics/2018/nsb20181/

[6] NSF, "NSF's National Science Board announces new leadership for 2018-2020," https://www.nsf.gov/nsb/news/news_summ.jsp?cntn_id=245368

[7] The current Vice-Chair of the NSB is Dr. Ellen Ochoa.

[8] According to OMB Uniform Guidance, a grant agreement is "a legal instrument of financial assistance between a Federal awarding agency or pass-through entity and a non-Federal entity that" ... "Is used to enter into a relationship the principal purpose of which is to transfer anything of value from the Federal awarding agency or pass-through entity to the non-Federal entity to carry out a public purpose." https://www.ecfr.gov/cgi-bin/text-idx?SID=46104990e1c2a6428d3e417781304a9f&mc=true&node=pt2.1.200&rgn=div5#se2.1.200_151

[9] NSF, "FY 2020 Budget Request to Congress", https://nsf.gov/about/budget/fy2020/index.jsp

[10] According to OMB Uniform Guidance, a cooperative agreement is "distinguished from a grant in that it provides for substantial involvement between the Federal awarding agency or pass-through entity and the non-Federal entity in carrying out the activity contemplated by the Federal award." https://www.ecfr.gov/cgi-bin/text-idx?SID=46104990e1c2a6428d3e417781304a9f&mc=true&node=pt2.1.200&rgn=div5#se2.1.200_124

research vessels; networked instrumentation and equipment; and large-scale computational infrastructure.

The total support for research infrastructure at NSF, including construction, operations and maintenance, is nearly a quarter of the agency's total budget. NSF funds construction and operations of major research facilities and equipment separately. One agency-wide account – the Major Research Equipment and Facilities Construction (MREFC) account – supports construction, while operations are funded through the research directorates.

Merit Review – The NSF proposal review and award process is based on competition between proposals within a specific scientific discipline or under an interdisciplinary initiative. Award selection involves input from individuals outside and within NSF, starting with a review panel made up of scientists and engineers with expertise in the relevant research area.

Every proposal is reviewed by multiple experts in the field and confidential feedback is made available to each proposer, allowing them to refine their proposal and increase their chance of success in the future. The panel evaluates proposals using two, NSB-approved criteria: (1) Intellectual Merit and (2) Broader Impacts. The NSF Merit Review Process is rigorous, highly competitive, and widely regarded as the "gold standard" for reviewing proposals in a competitive environment.

Big Ideas – While it maintains directorates organized around research disciplines, NSF has long supported cross-agency initiatives. As groundbreaking science has become increasingly interdisciplinary or transdisciplinary - the favored term today is "convergent" - the agency has experimented with different ways to break down cultural and institutional boundaries between disciplines. In 2016, Dr. Córdova unveiled 10 new ideas to drive NSF's long-term research agenda.

The 10 Big Ideas for Future NSF Investments are "meant to define a set of cutting-edge research agendas and processes that are uniquely suited for NSF's broad portfolio of investments, and will require collaborations with industry, private foundations, other agencies, science academies and societies, and universities."[11] The Big Ideas are divided into research and enabling ideas.[12]

Research Ideas
- Harnessing the Data Revolution
- Future of Work at the Human-Technology Frontier
- Navigating the New Arctic
- Quantum Leap
- Understanding the Rules of Life
- Windows on the Universe

Enabling Ideas
- Growing Convergence Research
- NSF INCLUDES
- Mid-scale Research Infrastructure
- NSF 2026

Convergence Accelerator – Starting with the FY 2019 budget request, NSF initiated a new model for accelerating goal-driven research in areas of national importance. The Convergence

[11] NSF, "10 Big Ideas for Future NSF Investments," https://www.nsf.gov/about/congress/reports/nsf_big_ideas.pdf
[12] An explanation of the 10 Big Ideas can be found here: https://www.nsf.gov/news/special_reports/big_ideas/

Accelerator stands separately from the research directorates and is divided into individual tracks. Each Convergence Accelerator track will be a time-limited entity that supports multidisciplinary research on specific topics or themes.

BUDGET REQUEST HIGHLIGHTS

The Administration's FY 2020 budget request includes $7.066 billion for NSF in FY2020, a $1.009 billion decrease (-12.5 percent) from the FY2019 enacted level of $8.075 billion. NSF has six appropriations accounts: Research and Related Activities (R&RA), Education and Human Resources (EHR), Major Research Equipment and Facilities Construction (MREFC), Agency Operations and Award Management (AOAM), National Science Board (NSB), and Office of Inspector General (OIG). The proposed cuts would come primarily from three accounts: R&RA by $857 million (13.1 percent), EHR by $87 million (9.5 percent), and MREFC by $73 million (24.5 percent). Since the FY 2019 spending plan for NSF has not yet been approved by Congress, this charter will compare the requested funding for programs within these accounts with NSF spending in FY 2018.

Program Activity	FY 2018 Actual	FY 2019 Enacted	FY 2020 Request	Change FY 2020 - 2018		Change FY 2020 - 2019	
				Amount	Percent	Amount	Percent
Research and Related Activities (R&RA)	6380.38	6520.00	5662.96	-717.42	-11.2	-857.04	-13.1
Education and Human Resources (EHR)	903.87	910.00	823.47	-80.40	-8.9	-86.53	-9.5
Major Research Equipment and Facilities Construction (MREFC)	186.30	295.74	223.23	36.93	19.8	-72.51	-24.5
Agency Operations	328.51	329.54	336.89	8.38	2.6	7.35	2.2
National Science Board	4.30	4.37	4.10	-0.20	-4.6	-0.27	-6.2
Inspector General	15.09	15.35	15.35	0.26	1.7	0.00	0.0
AGENCY TOTAL	**7818.43**	**8075.00**	**7066.00**	**-752.43**	**-9.6**	**-1009.00**	**-12.5**

Research – The Administration's FY 2020 budget proposal includes a $717 million (11.2 percent) cut to the R&RA account spread across the six research directorates relative to spending in FY 2018. Within this reduced budget, the Administration proposes increased or sustained support for priority research disciplines as follows: $492 million for artificial intelligence, $106 million for quantum science, and $268 million for advanced manufacturing. The budget also includes continued support for the 10 Big Ideas, with a total investment of nearly $690 million. Two of the big ideas, the Future of Work and Harnessing the Data Revolution, are the focus of the first two Convergence Accelerator tracks. Each of these tracks are funded at $30 million with the intention to leverage $20 million from external partnerships.

The proposed cut to research activities at NSF would result in 1,000 fewer early-stage research grants being awarded. The GEO and MPS directorate budgets are cut by 13 percent and 17 percent, respectively, and cuts to the remaining research directorates range from 8-10 percent.

Under this proposal, the agency-wide proposal funding rate would fall to 21 percent, and as low as 18 percent for the CISE and SBE directorates.

Education – The request proposes a $80 million (9 percent) cut for the Education and Human Resources directorate. This smaller budget includes increased funding for the Advanced Technological Education (ATE) program[13] (+$9 million or 14 percent) and the Discovery Research PreK-12 program[14] (+$6 million or 7 percent), however funding for most programs is reduced. The Robert Noyce Teacher Scholarship Program[15] is cut by $17.5 million (27 percent), the NSF Research Traineeship (NRT) program[16] is cut by $4 million (8 percent), and the Graduate Research Fellowship Program (GRFP)[17] is cut by $28 million (10 percent).

In addition to discipline-specific research activities, each research directorate allocates a portion of its budget to support education activities. Education investments across research directorates are cut by $78 million (35 percent) relative to FY 2018. With this budget, NSF activities would support 5,000 fewer researchers and postdoctoral associates, 6,500 fewer graduate and undergraduate students, and 24,000 fewer K-12 teachers and students.

Broadening Participation – While one of the Foundation's Big Ideas, NSF INCLUDES,[18] is provided with a $2 million (11 percent) increase, the budget proposal calls for cuts to nearly all other programs in NSF's broadening participation portfolio, a total reduction of $168 million (17 percent). For instance, the Established Program to Stimulate Competitive Research (EPSCoR) program[19] is cut by $19 million (11 percent) and the HBCU Excellence in Research program[20] is cut by $10 million (51 percent).

Facilities – The budget proposal provides $223 million to continue the construction of three ongoing major research infrastructure projects – the Antarctic Infrastructure Modernization for Science (AIMS)[21], the High Luminosity-Large Hadron Collider (HL-LHC)[22], and the Large Synoptic Survey Telescope (LSST)[23]. Also included is funding to support design activities for

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[13] The ATE program supports curriculum development; professional development of college faculty and secondary school teachers; career pathways; and other activities with an emphasis on two-year Institutions of Higher Education.

[14] The Discovery Research PreK-12 program supports research and development of STEM education.

[15] The Robert Noyce Teacher Scholarship Program provides educational opportunities for STEM majors and professionals to encourage them to become K-12 math and science teachers.

[16] The NRT program supports the development of innovative models for educating and training STEM graduate students.

[17] The GRFP program will be able to support 1,600 new fellows in FY 2020, compared with 2,000 in FY 2018.

[18] The INCLUDES program supports broadening participation research and the development of a diverse STEM workforce.

[19] The EPSCoR program supports improved research competitiveness for eligible geographic jurisdictions.

[20] The HBCU Excellence in Research Program supports improved research capacity and competitiveness of HBCUs.

[21] The AIMS project will replace major facilities at McMurdo Station, Antarctica, one of three permanent stations that comprise the U.S. presence in Antarctica, to meet anticipated science support requirements for the next 35 to 50 years.

[22] The HL-LHC project will upgrade the ATLAS and CMS detectors to enable them to record and analyze the large amounts of data produced by the upgraded LHC accelerator.

[23] The LSST, located in Chile, is an 8.4-meter optical telescope designed to carry out surveys of nearly half the sky.

potential future research facilities, including $400,000 for Advanced LIGO Plus (LIGO A+)[24] and $4 million for NSF's next leadership-class computing facility.[25]

To assist the research directorates in supporting the operations and management (O&M) of major facilities, and ease the budget pressure on core research activities, the request includes $10 million for a Facilities Operations Transition pilot program funded out of the Integrative Activities account. This funding is divided among three NSF facilities within the first five years of their operational life – the Ocean Observatories Initiative (managed by the GEO directorate), the National Ecological Observatory Network (BIO), and the Daniel K. Inouye Solar Telescope (MPS). The managing research directorates remain responsible for 90 percent of the O&M funding for these facilities.[26]

Mid-Scale Research Infrastructure – The proposal includes $75 million for mid-scale research infrastructure, split between the R&RA account (for projects in the $6-20 million range) and the MREFC account (for projects in the $20 – 70 million range). The mid-scale research infrastructure program is designed to address the gap in funding opportunities between the Major Research Instrumentation (MRI) and MREFC programs.[27] Support for mid-scale research infrastructure is in high demand, as demonstrated by the more than $3 billion in high-impact project ideas the agency received in response to a 2017 Request for Information.[28]

[24] The LIGO A+ instrument upgrades will increase the volume of space surveyed by a factor of four to seven.
[25] NSF's current leadership-class computing resource, Blue Waters at the University of Illinois at Urbana-Champaign (UIUC), will complete its operational cycle in December 2019. The next leadership-class computing system, the recently-funded Frontera system at the University of Texas at Austin, will be fully operational by July 2019.
[26] A 2018 NSB report called for greater flexibility within the MREFC account to supplement the responsibility of the research directorates for facilities (https://www.nsf.gov/pubs/2018/nsb201817/nsb201817.pdf). The budget request cites "challenges that would be introduced by maintaining separate construction and operations funding in the MREFC line" as the reason for requesting this funding in the R&RA account instead.
[27] Mid-scale research infrastructure includes projects ranging in cost from $20 - $60 million.
[28] NSB, "Bridging the Gap: Building a Sustained Approach to Mid-scale Research Infrastructure and Cyberinfrastructure at NSF," https://www.nsf.gov/nsb/publications/2018/NSB-2018-40-Midscale-Research-Infrastructure-Report-to-Congress-Oct2018.pdf

Chairwoman STEVENS. This hearing will come to order. Without objection, the Chair is authorized to declare recess at any time.

Good morning, and welcome to today's hearing to review the National Science Foundation (NSF) Fiscal Year 2020 Budget Request. Dr. Córdova and Dr. Souvaine, thank you for being here.

The National Science Foundation plays a critical role in advancing the U.S. scientific enterprise. NSF funding has enabled the inventions of things that have become commonplace in our lives: the first formal dictionary for American Sign Language, the development of barcodes, and the invention of the internet. I would like to congratulate both of our witnesses on the National Science Foundation's most recent breakthrough: the first image of a black hole.

As the only Federal science agency that supports basic research across all fields of science and engineering, NSF provides about one-fourth of all Federal support for basic research conducted at colleges and universities. For researchers in certain fields like computer science, biology, and social science, NSF is the primary source of Federal funding. NSF is also the principal source of Federal support for STEM (science, technology, engineering, and mathematics) education at all levels and in all settings, from pre-kindergarten through career development. This work enables the United States to lead the world in science and innovation, compete in the global economy, and protect the health and security of our citizens.

Funding for the NSF has steadily increased in recent years thanks to Congress rejecting repeated proposals for cuts from the current Administration. The agency's budget exceeded $8 billion for the first time in Fiscal Year 2019.

I will start with good news. I applaud the agency for sustaining its commitment to the 10 Big Ideas. I am also glad to see full funding for the construction of major research facilities like the Antarctic Infrastructure Modernization Project and Large Synoptic Survey Telescope. Cutting-edge equipment and facilities are essential for researchers to push the boundaries of knowledge and for training the next generation of top scientists.

I also appreciate the prioritization of artificial intelligence, the future of work, and quantum science, two areas which will be critical for U.S. economic and national security. It is also safe to say that the world is waiting and eager for our leadership in these areas. I'm happy to see the increases in some areas—the budget increases, that is—for these two important focuses on research in the Fiscal Year 2020 budget proposal.

Unfortunately, though, we continue to see a concerning lack of understanding around the importance of science and yet again another round of drastic cuts in funding for scientific research proposed by the current Administration. The Fiscal Year 2020 request proposes to cut a full $1 billion from the National Science Foundation budget.

Henceforth, the role of Congress shall be exercised. We are here today to evaluate the merits of these cuts, and, as Chair of this Subcommittee on Research and Technology with oversight of the NSF, I can unequivocally say that such a cut would threaten our Nation's leadership in science and technology across all fields of science and engineering. Despite some of the interagency increases in AI and Quantum, making this a zero-sum game by cutting other

fields of science and engineering and eroding the foundational backbone of all emerging technologies is unwise at best.

The Fiscal Year 2020 budget proposal would also slow progress in STEM education, including efforts to increase diversity in our STEM workforce, the topic of a Full Committee hearing led by our fabulous Full Committee Chair Eddie Bernice Johnson that we are having later this week.

We are seeing a surge in demand for workers with STEM skills across all sectors, and educators are struggling to keep up. Within months of releasing its 5-year strategic plan in STEM education, the current Administration put forward a proposal to gut STEM education programs governmentwide. It worries me that we are eager to talk about science and scientific innovation in platitudes, and yet we fail to put forward a strategic investment plan that would enable us to compete and win in global marketplaces. The current proposal represents a vision for science that, if realized, would be disastrous for our Nation's long-term welfare, security, and competitiveness.

Dr. Córdova, I appreciate the leadership and background and experience that you and Dr. Souvaine bring to this agency. I look forward to a discussion with both of you today on the value of the National Science Foundation as a national asset and the potential impacts of these cuts.

[The prepared statement of Chairwoman Stevens follows:]

U.S. HOUSE OF REPRESENTATIVES COMMITTEE ON
SCIENCE, SPACE, & TECHNOLOGY

Opening Statement

Chairwoman Haley Stevens (D-MI)
of the Subcommittee on Research and Technology

Subcommittee on Research and Technology Hearing:
A Review of the National Science Foundation FY 2020 Budget Request
May 8, 2019

Good morning and welcome to today's hearing to review the National Science Foundation Fiscal Year 2020 Budget Request. Dr. Córdova and Dr. Souvaine, thank you for being here.

The National Science Foundation plays a critical role in advancing the U.S. scientific enterprise. NSF funding has enabled the inventions of things that have become commonplace in our lives: the first formal dictionary for American Sign Language, the development of bar codes, and the invention of the Internet. I would like to congratulate you both on the National Science Foundation's most recent breakthrough: the first image of a black hole.

As the only federal science agency that supports basic research across all fields of science and engineering, NSF provides about a quarter of the all federal support for basic research conducted at colleges and universities. For researchers in certain fields, like computer science, biology, and social science, NSF is the primary source of federal funding. NSF is also the principal source of federal support for STEM education at all levels and in all settings, from pre-kindergarten through career development. All of this enables the United States to lead the world in science and innovation, compete in the global economy, and protect the health and security of its citizens.

Funding for the NSF has steadily increased in recent years thanks to Congress rejecting repeated proposals for cuts from this President. The agency's budget exceeded $8 billion for the first time in FY 2019.

I'll start with the good news. I applaud the agency for sustaining its commitment to the 10 Big Ideas. I am also glad to see full funding for the construction of major research facilities like the Antarctic Infrastructure Modernization Project and Large Synoptic Survey Telescope. Cutting-edge equipment and facilities are essential for researchers to push the boundaries of knowledge and for training the next generation of top scientists.

I also appreciate the prioritization of Artificial Intelligence and Quantum Science, two areas which will be critical for U.S. economic and national security. I'm happy to see increases in some areas for these two important areas of research in the FY 2020 budget proposal.

Unfortunately, this Administration continues to display a concerning lack of understanding of the importance of science with yet another round of drastic cuts in funding for scientific research across the government. The fiscal year 2020 request proposes to cut a full $1 billion from the National Science Foundation budget.

Such a cut would threaten our nation's leadership in science and technology across all fields of science and engineering. Despite the increases in AI and Quantum, making this a zero-sum game by cutting other fields of science and engineering and eroding the foundational backbone of all emerging technologies is unwise at best.

The FY 2020 budget proposal would also slow progress in STEM education, including in diversifying our STEM workforce, the topic of a full committee hearing in this Committee tomorrow. We are seeing a surge in demand for workers with STEM skills across all sectors and educators are struggling to keep up. Within months of releasing its 5-year strategic plan in STEM education, the Administration put forth a proposal to gut STEM education programs government-wide.

It worries me that this Administration does not truly understand the importance of scientific funding to our nation's innovation goals. This proposal represents a vision for science that, if realized, would be disastrous for our nation's long-term welfare, security, and competitiveness.

Dr. Córdova, I appreciate the leadership of you and Dr. Souvaine, and I look forward to a discussion with you both about the value of the National Science Foundation as a critical national asset and the potential impacts of these cuts.

Thank you.

Chairwoman STEVENS. Now, I would like to recognize our Ranking Member, Mr. Baird, for an opening statement.

Mr. BAIRD. Thank you, Chairwoman Stevens, and thank you for convening today's hearing for this Fiscal Year 2020 budget request for the National Science Foundation. And I really want to thank our witnesses for being here today as well. I appreciate that. I am looking forward to this opportunity to learn more about the National Science Foundation and its mission to promote the progress of science.

The NSF is the only Federal agency that supports basic research across all scientific fields from biology to physics. As a trained Ph.D. scientist, I know that basic research is the seed that grows into the products and solutions that drive our economy and improve our lives. The NSF plays a critical role in helping educate and train the next generation of STEM workers, and we need to invest in young people who will go into fields where there is a national need and good-paying jobs.

Earlier this year, I joined Chairwoman Stevens in introducing the *Building Blocks of STEM Act*. I look forward to moving the bill forward and working with NSF to make sure we're giving young students a foundation to continue in the STEM studies. For the United States to remain competitive, we must ensure that as many people as possible have the opportunity to participate in STEM fields and build valuable, fulfilling careers.

In my district, I am proud to represent Purdue University, Indiana's Land Grant University, as Dr. Córdova well knows. NSF funded nearly $68 million in groundbreaking research at Purdue last year. To share just one example, NSF funded an engineering research center at Purdue, which is developing new technologies to produce fuels from U.S. shale-gas deposits that could inject $20 billion annually into our economy. This is an example of the potential impact of NSF-funded research.

As we've heard, the President's budget request for NSF is just over $7 billion, a 12.5 percent decrease from last year's enacted funding. Like all other agencies and departments, NSF was forced to take and make tough decision and choices. The budget request reflects an attempt to set priorities in a constrained budgetary environment. The budget request prioritizes funding for critical areas like artificial intelligence, quantum technology, and advanced manufacturing. I look forward to hearing about these new investments in today's testimony.

But the President's budget proposal is just that. It's just a budget proposal. It's ultimately up to Congress to decide at what level NSF is funded. We have a constitutional obligation and a responsibility to ensure every taxpayer dollar spent is used as effectively and efficiently as possible. I appreciate that today's hearing gives us the opportunity to fulfill that duty.

And I thank the witnesses for being here today and yield back my balance of time.

[The prepared statement of Mr. Baird follows:]

Opening Statement of Ranking Member Jim Baird at R&T Subcommittee Hearing on FY20 NSF Budget

May 8, 2019

Opening Statement

Good morning Chairwoman Stevens. Thank you for convening today's hearing on the Fiscal Year 2020 budget request for the National Science Foundation (NSF). I appreciate this opportunity to learn more about the National Science Foundation and its mission to promote the progress of science.

The NSF is the only federal agency that supports basic research across all scientific fields from biology to physics.

As a trained PhD scientist, I know that basic research is the seed that grows into the products and solutions that drive our economy and improve our lives.

The NSF also plays a critical role in helping educate and train the next generation of STEM workers. We need to invest in young people who will go into fields where there is a national need and good paying jobs.

Earlier this year, I joined Chairwoman Stevens in introducing the Building Blocks of STEM Act. I look forward to moving that bill forward and working with NSF to make sure we are giving young students a foundation to continue in STEM studies.

For the U.S. to remain competitive, we must ensure that as many people as possible have the opportunity to participate in STEM fields and build valuable, fulfilling careers.

In my district, I am proud to represent Purdue University, Indiana's Land Grant University. NSF funded nearly $68 million in groundbreaking research at Purdue last year. To share just one example, NSF is funding an engineering research center at Purdue, which is developing new technologies to produce fuels from U.S. shale-gas deposits that could inject $20 billion annually into the economy. This is an example of the potential impact of NSF funded research.

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The budget request prioritizes funding for critical areas like artificial intelligence, quantum technology, and advanced manufacturing. I look forward to hearing about these new investments.

But the president's budget proposal is just that, a budget proposal. It's ultimately up to Congress to decide at what level NSF is funded.

We have a constitutional obligation and a responsibility to ensure every taxpayer dollar spent is used as effectively and efficiently as possible. I appreciate that today's hearing gives us the opportunity to fulfil that duty.

I thank the witnesses for being here today and yield back the balance of my time.

Chairwoman STEVENS. At this time the Chair now recognizes the Chairwoman of the Full Committee, Ms. Johnson, for an opening statement.

Chairwoman JOHNSON. Good morning, and thank you, Chairwoman Stevens and Ranking Member Dr. Baird, for holding this hearing to review the National Science Foundation budget request for Fiscal Year 2020. And thank you, Dr. Córdova and Dr. Souvaine, for being here this morning. It is good to have both of you again.

The National Science Foundation, during its nearly 70-year history, has played a critical role in promoting our economic prosperity, national security, and the health and well-being of our population. It should come as no surprise that nations around the world, including some of our rivals, have attempted to replicate NSF in their own governments. This is why I'm dismayed that the budget that has been sent over by the White House proposes to cut NSF by a $1 billion. A cut like that would keep us from funding excellent research and slow progress in critical areas of technology development.

Unfortunately, this is a pattern that we've seen from this White House over the past three budget cycles. To make matters worse, the recent shut down of much of our government for 35 days, including the National Science Foundation, resulted in delays for 2,000 grant applications. While there may seem to be minor to some, delays in grant funding derail academic careers, sometimes permanently.

Increasingly, U.S. students and early career researchers are packing up for better opportunities abroad or leaving STEM altogether. I have no doubt that we have the brainpower in this country to continue to lead but not if we chase away our own best and brightest and close our doors to the best and brightest from around the world. I'm an optimist, but I also recognize the sobering realities of increasing competition, a growing skills gap, and crumbling research infrastructure.

We also gain from international collaboration, and other countries investing more in R&D is overall a good thing. However, we must maintain our investments to reap the benefits of collaboration and protect our economic and national security interests.

Some of my colleagues will say this is just a proposal, and Congress has the final say in the budget. However, until Congress acts, the agency and researchers can only plan according to what's in the Administration's proposal.

Moreover, Congress itself has become too comfortable with passing one short-term continuing resolutions one after another that has done harm as well. Tomorrow morning, this Committee will hold its first hearing since 2010 assessing the state of diversity in STEM.

The NSF budget proposal includes $168 million in cuts to NSF investment in broadening participation. The Administration proposes to eliminate the STEM Partnerships Program and significantly cut the Noyce Teacher Scholarship Program. These proposed cuts are included, despite this Administration prioritizing diversity in its recent governmentwide STEM strategic plan. A commitment

to addressing our Nation's challenges must involve more than just words.

Dr. Córdova, I do not question your commitment, nor the commitment of the talented, hardworking staff around the—across the National Science Foundation. I know you did your best with a very challenging top line. But we cannot just keep pretending year after year that everything is going to be OK because Congress will restore the National Science Foundation's funding.

As the months tick by between now and then, more students and researchers across our Nation will lose hope that the United States is still the best country in the world to be a scientist. Our Nation's leadership, on both sides of the aisle, must provide the support our students and researchers need to apply their knowledge and talents to the betterment of our society. I truly hope, going forward, we can do better than we have been.

I look forward to the testimony and discussion, and I yield back. Thank you.

[The prepared statement of Chairwoman Johnson follows:]

U.S. HOUSE OF REPRESENTATIVES COMMITTEE ON
SCIENCE, SPACE, & TECHNOLOGY
Opening Statement

Chairwoman Eddie Bernice Johnson (D-TX)

Subcommittee on Research and Technology Hearing:
A Review of the National Science Foundation FY 2020 Budget Request
May 8, 2019

Thank you Chairwoman Stevens and Ranking Member Baird for holding this hearing to review the National Science Foundation budget request for fiscal year 2020. And thank you Dr. Còrdova and Dr. Souvaine for being here this morning. It is good to see you both again.

The National Science Foundation, during its nearly 70-year history, has played a critical role in promoting our economic prosperity, national security, and the health and wellbeing of our population. It should come as no surprise that nations around the world, including some of our rivals, have attempted to replicate NSF in their own governments.

That is why I'm so dismayed that the budget that has been sent over by the White House proposes to cut NSF by a $1 billion. A cut like that would keep us from funding excellent research and slow progress in critical areas of technology development. Unfortunately, this is a pattern we've seen from this White House over the past three budget cycles. To make matters worse, the recent shut down of much of our government for 35 days, including the National Science Foundation, resulted in delays for 2,000 grant applications. While that may seem minor to some, delays in grant funding derail academic careers, sometimes permanently. Increasingly, U.S. students and early career researchers are packing up for better opportunities abroad or leaving STEM altogether.

I have no doubt that we have the brainpower in this country to continue to lead, but not if we chase away our own best and brightest and close our doors to the best and brightest from around the world. I am an optimist, but I also recognize the sobering realities of increasing competition, a growing skills gap, and crumbling research infrastructure. We also gain from international collaboration, and other countries investing more in R&D is overall a good thing. However, we must maintain our own investments to reap the benefits of collaboration and protect our economic and national security interests.

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what's in the Administration's proposal. Moreover, Congress itself has become too comfortable with passing one short-term continuing resolution after another, and that has done harm too.

Tomorrow morning this Committee will hold its first hearing since 2010 assessing the state of diversity in STEM. The NSF budget proposal includes $168 million in cuts to NSF's investments in broadening participation. The Administration proposes to eliminate the STEM Partnerships Program and significantly cut the Noyce Teacher Scholarship Program. These proposed cuts are included despite this Administration prioritizing diversity in its recent government-wide STEM strategic plan. A commitment to addressing our nation's challenges must involve more than just words.

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I look forward to the testimony and discussion and I yield back.

Chairwoman STEVENS. At this time, the Chair now recognizes the Ranking Member of the Full Committee, Mr. Lucas, for an opening statement.

Mr. LUCAS. Thank you, Chairwoman Stevens and Ranking Member Baird, for holding this hearing to review the National Science Foundation's priorities for the year 2020.

Since its creation in 1950, the National Science Foundation has played a critical role in advancing science for America's national defense and economic security. Basic research supported by NSF forms the foundation of discoveries that fuels private-sector development. It also provides a training ground for our Nation's scientists, engineers, and other STEM workers.

We've heard concerns about some of the proposed cuts included in the Administration's request. I would remind my colleagues that the President's budget request is just a starting point for our discussions, as have all previous Presidents' budgets been. We're here today to learn more about how best to prioritize NSF's resources. It is also important to note that in recent years Congress has decided to fund NSF at a higher rate than the President's budget request.

I believe the Federal Government has a responsibility to prioritize basic research and development. This Committee has demonstrated a long history of bipartisan support for the work of the National Science Foundation. As the Ranking Member, I am committed to working with Chairwoman Johnson and the appropriators to continue that support. However, as I said at a hearing earlier this year on American Competitiveness in Science and Technology, we need to collectively do a better job of explaining why science matters to all Americans.

NSF has a great story to tell. NSF-funded research is helping address some of the Nation's most critical needs from treating opioid addiction to bringing high-speed broadband to rural areas across the country. In my home State of Oklahoma, NSF invests $25 million a year in research and STEM education. NSF is working with the University of Oklahoma on improving forecasting of supercell thunderstorms. At Oklahoma State, NSF is funding a program to give scientists the skills to be entrepreneurs and start new small businesses.

At townhalls throughout my district in Oklahoma, I talk to my constituents not just about the work that NSF and our other science agencies are doing, but, more importantly, why it matters to them. I'm sure my colleagues here do the same. And NSF can do even more to help create a culture that both values and prioritizes R&D.

I look forward to working with the leadership of the National Science Foundation and the National Science Board to meet this challenge and ensure America continues to lead in technological advancement.

Thank you to witnesses Dr. Córdova and Dr. Souvaine for your leadership and being here today to testify, and I yield back, Madam Chairman.

[The prepared statement of Mr. Lucas follows:]

Opening Statement of Ranking Member Frank Lucas at R&T Subcommittee Hearing on FY20 NSF Budget

May 8, 2019

Opening Statement

Thank you, Chairwoman Stevens and Ranking Member Baird for holding this hearing to review the National Science Foundation's priorities for Fiscal Year 2020.

Since its creation in 1950, the National Science Foundation (NSF) has played a critical role in advancing science for America's national defense and economic security.

Basic research supported by NSF forms the foundation of discoveries that fuel private sector development. It also provides a training ground for our nation's scientists, engineers, and other STEM workers.

We have heard concerns about some of the proposed cuts included in the Administration's request. I would remind my colleagues that the President's budget request is just a starting point for our discussions.

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And the NSF can do even more to help create a culture that both values and prioritizes R&D.

I look forward to working with the leadership of the National Science Foundation and the National Science Board to meet this challenge and ensure America continues to lead in technological advancement.

Thank you to our witnesses Dr. Cordova and Dr. Souvaine for your leadership and for being here today to testify.

Chairwoman STEVENS. At this time I'd like to introduce our witnesses, and if you're looking for two inspiring, strong women in the field of science, look no further than our expert witnesses here before us today. Our first witness is Dr. France Córdova. Dr. Córdova was confirmed as the 14th Director of the National Science Foundation in 2014. Dr. Córdova is President Emerita of Purdue University and Chancellor Emerita of the University of California Riverside. Previously, she was Chief Scientist at NASA, and Dr. Córdova received her bachelor of arts degree from Stanford University and her doctorate in physics from the California Institute of Technology.

Our next witness is Dr. Diane Souvaine. Dr. Souvaine is currently the Chair of the National Science Board, the NSB, a position that she has held since 2018. She is also a Professor of Computer Science and an Adjunct Professor of Mathematics at Tufts University. She was previously Vice Chair from 2016 to 2018 of the NSB and has chaired the NSB's Committee on Strategy and Budget, its Committee on Programs and Plans, and has served on its Committee on Audit and Oversight. Dr. Souvaine received her master's and doctorate degrees in computer science from Princeton University.

As our witnesses should know, you will each have 5 minutes for your spoken testimony.

And, well, let me actually run back here, too, because we jumped over with our opening statements, and I do want to make a mention that if any other Members who wish to submit opening statements, additional opening statements, they could either be submitted at this point or into the record, so we're—you know, if people want to do that, that's great.

As we jump to our witness testimony, though, you'll have the 5 minutes. When you've completed your spoken testimony, we will begin with questions, and each Member on the Subcommittee will have 5 minutes to question you.

And so, right now, we will start with Dr. Córdova.

TESTIMONY OF DR. FRANCE CÓRDOVA, DIRECTOR, NATIONAL SCIENCE FOUNDATION

Dr. CÓRDOVA. Thank you, Chairwoman Stevens, Ranking Member Dr. Baird, and Members of the Subcommittee, Chairwoman Johnson, Ranking Member Lucas. It's a pleasure to be with you today and thank you for your stirring, inspiring words.

The President's Fiscal Year 2020 budget request for the National Science Foundation is $7.1 billion. This request makes targeted investments in basic research within the constrained budget environment. My written testimony contains the details of the Fiscal Year 2020 request. I'd like to take the next few minutes to focus on the importance of NSF's mission and our Fiscal Year 2020 investments.

Last month, NSF and the Event Horizon Telescope team brought the world the first-ever image of a black hole. This amazing feat of global cooperation and ingenuity in science and engineering underscores NSF's unique and incredibly valuable mission. We fund the most promising basic research in all disciplines of science and engineering, and every major newspaper of the world had that

image on it. It was absolutely amazing. Talk about bringing science to people—very inspiring.

Our track record of making wise investments is strong. Since its creation in 1950, NSF has supported 236 Nobel Prize winners at some point in their careers. Over the past 70 years, NSF's mission has contributed greatly to our country's economic prosperity, our national security, our health, and our global leadership in innovation.

Basic research lays the foundation upon which progress is built. Without it, we would not have many of the modern-day technologies and advancements that are so ubiquitous in our lives. For example, NSF played a critical role in additive manufacturing, which has revolutionized the way we conceive of and build everything from electronic devices to artificial organs. NSF has also given early support to visionary entrepreneurs that have developed major companies like Qualcomm, Symantec, and Google. Google alone has seen a 200,000fold return on NSF's original investment.

From the discovery of a microbe's enzyme in the Hot Springs of Yellowstone National Park that makes modern DNA fingerprinting possible to computer devices that help elementary school students learn, NSF supports the discoveries and the discoverers that keep the United States at the leading edge of innovation. Paul Romer, co-winner of the 2018 Nobel Prize for Economics, has emphasized that human capital, innovation, and knowledge are vital contributions to economic growth.

The Fiscal Year 2020 budget request contains two cornerstones of NSF's vision for the future: the 10 Big Ideas and the Convergence Accelerator. NSF's 10 Big Ideas define a set of cutting-edge research agendas that are uniquely suited for its broad portfolio of investments and will require collaborations with industry, academia, and others. Each of the 10 Big Ideas was chosen to be a catalyst for fundamental research that will expand the boundaries of our knowledge from the cellular level to the cosmos. For instance, understanding how new technologies are shaping the lives of workers and how people in turn can shape those technologies, that's the focus of NSF's Big Idea on The Future of Work.

Also important is the Convergence Accelerator, which will be focused on high-risk, high-reward innovative thinking to accelerate discovery and innovation and achieve rapid lab-to-market outcomes.

We're also making significant investments to continue U.S. leadership in artificial intelligence, quantum information science, and advanced manufacturing. Public-private partnerships have long been one of NSF's core strategies. As we look to the future in these and other areas, they'll be even more important.

We continue to invest in large-scale research facilities that keep the United States at the forefront of discovery—deploying a new supercomputer at the University of Texas, completing the construction of the solar telescope DKIST and the optical observatory LSST, and modernizing the Antarctic facilities of which NSF is the steward for the Nation.

NSF is also proposing dedicated funding for the scientific infrastructure that falls between our smaller programs and large construction projects. The need for mid-scale funding has been called

out by Congress, the National Academies, and the National Science Board.

Perhaps most importantly, we continue to invest in people. Discoveries don't happen without discoverers. We must continue to light the imagination of the next generation and support and nurture their curiosity. Thus, NSF is focused on advancing excellence in STEM education at all levels and in all settings to support the development of a diverse and well-prepared workforce.

NSF's Advanced Technological Education program involves partnerships between academic institutions and industries to prepare science and engineering technicians in the industries of the future. The vast majority of those projects are situated in community colleges.

I'd be remiss not to also thank Congress for the strong support provided for NSF's mission, especially in Fiscal Year 2019. With that funding, we're making investments that keep the United States at the cutting edge of scientific discovery and Americans leading the world in scientific achievement.

Thank you for your time today and for your continued strong support of NSF and our mission.

[The prepared statement of Dr. Córdova follows:]

Dr. France Córdova
Director
National Science Foundation

Before the
Subcommittee on Research and Technology
Committee on Science, Space and Technology
United States House of Representatives

on
"A Review of the NSF FY2020 Budget Request"

May 8, 2019

Introduction

Chairwoman Stevens, Ranking Member Baird, and Members of the subcommittee, it is a privilege to be here with you today to discuss the President's Fiscal Year (FY) 2020 Budget Request for the National Science Foundation (NSF).

Established by the National Science Foundation Act of 1950 (P.L. 81-507), NSF is an independent Federal agency whose mission is "to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense; and for other purposes." NSF is unique in carrying out its mission by supporting fundamental research across all fields of science, technology, engineering and mathematics (STEM) and all levels of STEM education. NSF is also committed to the development of a future-focused science and engineering workforce that draws on the talents of all Americans. NSF accounts for approximately 25 percent of the total Federal budget for basic research conducted at U.S. colleges and universities and has been vital to many discoveries that impact our daily lives and drive the economy. NSF is and will continue to be a respected steward of taxpayer dollars, operating with integrity, openness, and transparency.

A vibrant scientific workforce and breakthrough discoveries enabled by NSF investments sustain, accelerate, and transform America's globally preeminent innovation ecosystem. A long-term vision, belief in the promise of fundamental research, and commitment to pursuing risky, yet potentially extraordinary discoveries are the hallmarks of NSF. NSF's investments empower discoverers to ask the questions and develop the technologies that lead to the next big breakthroughs.

This was most recently illustrated by the Event Horizon Telescope (EHT) team's successful work to produce the first image of a black hole. EHT used a planet-scale array of eight ground-based radio telescopes forged through international collaboration to image the black hole at the center of Messier 87, a massive galaxy in the nearby Virgo galaxy cluster. This black hole resides 55 million light-years from Earth. This momentous achievement was the product of a team building on decades of investment in telescopes, computing, and training the next generation of scientists.

In FY 2020, NSF will continue to support the science, technology, innovation and workforce development that drives this Nation's economy, ensures the security of the American people, and guarantees the United States' place as a global power for generations to come. To achieve these goals, NSF will make strategic investments across the agency to support basic research, while putting an emphasis on convergence—interdisciplinary research that spans and integrates all areas of science.

NSF has made a strong commitment to agency-supported research infrastructure. In FY 2020, NSF is requesting $1.089 billion for its major multi-user research facilities, including for construction in the MREFC account. Major NSF research facilities range from research stations in Antarctica, to a fleet of academic research ships, to a suite of world-leading telescopes. This research infrastructure is critical for delivering frontier scientific results such as detections of gravitational waves and supports the research of tens of thousands of U.S. scientists and students.

In addition, FY 2020 investments support several of the Administration's Research and Development Budget Priorities, including artificial intelligence (AI); quantum information science (QIS) research; advanced manufacturing; and microelectronics and semiconductors. These investments will strengthen the Nation's innovation base and contribute to unparalleled job growth, continued prosperity, and national security.

In FY 2020, NSF expects to evaluate approximately 46,100 proposals through a competitive merit review process and make approximately 10,400 new competitive awards, 8,000 of which will be new research grants and the remainder of which will be contracts and cooperative agreements. The number of new research grants decreases by roughly 11 percent from previous levels, in keeping with the overall change in total NSF funding. This process involves approximately 224,000 proposal reviews, engaging on the order of 32,000 members of the science and engineering community participating as panelists and proposal reviewers. In a given year, NSF awards reach over 1,800 colleges, universities, and other public and private institutions in 50 states, the District of Columbia, and U.S. territories. In FY 2020, NSF support is expected to reach approximately 348,400 researchers, postdoctoral fellows, trainees, teachers, and students, with 93 percent of the agency's annual budget used to fund research and education grants and research infrastructure in the science and education communities.

The President's Fiscal Year 2020 Budget Request

NSF's FY 2020 Budget Request is $7.066 billion, a 9.6 percent decrease from the FY 2018 Actual level and a 12.6 percent decrease from the FY 2019 Enacted level. With this level of funding, NSF will support basic research across all fields of science and engineering that create knowledge while investing in priority areas like:

- Advancing NSF's Big Ideas - bold questions that will drive NSF's long-term research agenda;

- Accelerating focused, cross-disciplinary efforts that will have impact in a short timeframe around two of the Big Ideas: Harnessing the Data Revolution and the Future of Work at the Human-Technology Frontier.
- Research and Development Priorities such as AI and Quantum Information Science.
- Continuing the Antarctic Infrastructure Modernization for Science project; and
- Investing in two detector upgrades to operate at the High Luminosity-Large Hadron Collider (HL-LHC).

NSF's BIG IDEAS

Increasingly, collaboration and convergence are necessary to achieving our mission, especially in a world of constrained budgets. NSF continues to emphasize its 10 Big Ideas, research agendas that identify areas at the frontiers of science and engineering, which promise to be among the most transformative in the coming decade. Of the 10 Big Ideas, six are identified as research ideas. These are opportunities for researchers to make the discoveries that will shape the future of everything from quantum computing, artificial intelligence, and agriculture to space exploration and medical innovation. Each of these Big Ideas will be supported by an investment in dedicated activities for the Idea, as well as additional foundational investments from across the agency. The other four are Enabling Big Ideas, which endeavor to make science and engineering more interdisciplinary and reflective of the rich diversity of the U.S., while supporting investments in infrastructure and risky, high-reward science. New agency FY 2020 investment in the Research Big Ideas is $180.0 million. For Enabling Big Ideas, the FY 2020 investment totals $117.5 million. NSF's 10 Big Ideas are as follows:

Research Big Ideas:

1. ***Harnessing the Data Revolution for 21st-Century Science and Engineering (HDR)***—Engaging NSF's research community in the pursuit of fundamental research in data science and engineering, the development of a cohesive, federated, national-scale approach to research data infrastructure, and the development of a 21st-century data-capable workforce.

2. ***The Future of Work at the Human Technology Frontier (FW-HTF)***—Catalyzing interdisciplinary science and engineering research to understand and build the human-technology relationship, design new technologies to augment human performance, illuminate the emerging socio-technological landscape, and foster lifelong and pervasive learning with technology.

3. ***Windows on the Universe (WoU): The Era of Multi-Messenger Astrophysics***—Using powerful new syntheses of observational approaches to provide unique insights into the nature and behavior of matter and energy and to answer some of the most profound questions before humankind.

4. ***The Quantum Leap (QL): Leading the Next Quantum Revolution***—Exploiting quantum mechanics to observe, manipulate, and control the behavior of particles and energy at atomic and subatomic scales; and developing next-generation quantum-enabled science and technology for sensing, information processing, communicating, and computing.

5. ***Understanding the Rules of Life (URoL): Predicting Phenotype***—Elucidating the sets of rules that predict an organism's observable characteristics, i.e., its phenotype.

6. ***Navigating the New Arctic (NNA)***—Establishing an observing network of mobile and fixed platforms and tools, including cyber tools, across the Arctic to document and understand the Arctic's rapid biological, physical, chemical, and social changes, in partnership with other agencies, countries, and native populations.

Enabling Big Ideas:

7. ***NSF INCLUDES***—Transforming education and career pathways to help broaden participation in science and engineering.

8. ***Growing Convergence Research at NSF (GCR)***—Merging ideas, approaches, tools, and technologies from widely diverse fields of science and engineering to stimulate discovery and innovation.

9. ***Mid-scale Research Infrastructure***—Developing an agile process for funding experimental research capabilities in the mid-scale range, spanning the midscale gap in research infrastructure. This is a "sweet spot" for science and engineering that has been challenging to fund through traditional NSF programs.

10. ***NSF 2026 Fund***—Stimulating and seeding investments in bold foundational research questions that are large in scope, innovative in character, originate outside of any particular NSF directorate, and may require a long-term commitment. This Big Idea is framed around the year 2026, providing an opportunity for transformative research to mark the Nation's 250th anniversary.

CONVERGENCE ACCELERATOR

In the FY 2019 Budget Request to Congress, NSF unveiled the Convergence Accelerator, a new organizational framework that stands separately from the NSF research directorates, with its own budget, staff, and initiatives. The Convergence Accelerator will be a time-limited entity focused on specific research topics and themes. Those topics and themes will reward high-risk, innovative thinking to accelerate the discovery and innovation that remains the priority of NSF. The Accelerator is intended to be a new way of achieving rapid lab-to-market outcomes.

In FY 2020, the Convergence Accelerator will focus on topics shared by two of the 10 Big Ideas. One Accelerator track will focus on Harnessing the Data Revolution for 21st-Century Science and Engineering, and a second will focus on the Future of Work at the Human-Technology Frontier. Each will be funded at $30.0 million, plus each will seek to leverage $20.0 million in external partnerships.

NSF's support for the Big Ideas and the Convergence Accelerator reflects the agency's ongoing commitment to advancing science at the frontiers, while supporting the core fundamental research that has advanced the Nation since the agency's founding. Collaboration and convergence are required across NSF to achieve the agency's mission and support the maximum number of researchers. Science and engineering today requires innovative approaches to leveraging resources across all fields of science.

RESEARCH AND DEVELOPMENT PRIORITIES

Basic research forms the core of NSF's work and has led to discoveries and innovations that have been awarded hundreds of Nobel Prizes, and changed humankind's conception of the universe and the known world. Basic research is responsible for advancing our knowledge of the universe, as well as innovations like high speed internet, nanotechnology, and advances in robotics that require understanding of the fundamental laws that govern the physical world. NSF funds basic research in all the agency's directorates and continues to fund research that transcends single disciplines.

In FY 2020, NSF will make investments that support the basic research that advances human knowledge and makes tomorrow's innovations possible. Additional investments will support the advancement of AI, research in advanced manufacturing, and advance discoveries in QIS and semiconductors and microelectronics research.

Artificial Intelligence

AI is advancing rapidly and holds the potential to transform American lives through improved educational opportunities, increased economic prosperity, and enhanced national and homeland security. NSF will continue significant investment in AI with **$492.0 million** in AI research in FY 2020. NSF supports fundamental research in machine learning, computer vision, and natural language processing, along with the safety, security, robustness, and explainability of AI systems; translational research at the intersection of AI and various science and engineering domains as well as economic sectors such as agriculture, manufacturing, and personalized medicine; and education and learning, including growing human capital and institutional capacity to nurture a next generation of AI researchers and practitioners.

Advanced Manufacturing

In FY 2020, NSF will invest **$268.0 million** in Advanced Manufacturing and continue to support the fundamental research needed to revitalize American manufacturing to grow the national prosperity and workforce, and to reshape our strategic industries. NSF research accelerates advances in manufacturing technologies with an emphasis on multidisciplinary research that fundamentally alters and transforms manufacturing capabilities, methods and practices. Investments in advanced manufacturing include research on highly connected cyber-physical systems in smart processing and cyber manufacturing systems, and activities that develop new methods, processes, analyses, tools, or equipment for new or existing manufacturing products, supply chain components, or materials. NSF's investments are expected to enable new functionalities to increase the efficiency and sustainability of the production of the next generation of products and services. These developments will yield advantages such as reduced time to market, new performance attributes, improved small-batch production, cost savings, energy savings, or reduced environmental impact from the manufacturing of products.

Quantum Information Science

Research in QIS examines uniquely quantum phenomena that can be harnessed to advance information processing, transmission, measurement, and fundamental understanding in ways that classical approaches can only do much less efficiently, or not at all. NSF will invest **$106.0 million** in QIS research and development in FY 2020, which strongly aligns with the Administration's priorities and the National Quantum Initiative to consolidate and expand the U.S.' world-leading position in fundamental quantum research and deliver proof-of-concept

devices, applications, tools, or systems with a demonstrable quantum advantage over their classical counterparts.

Microelectronics

Research in semiconductors and microelectronics is critical to future advances and security in several areas, including information technology, communications, sensing, smart electric grid, transportation, health, and advanced manufacturing. NSF will support research to address fundamental science and engineering questions on the concepts, materials, devices, circuits, and platforms necessary to sustain progress in semiconductor and microelectronic technologies. The FY 2020 investment of **$68.0 million** will strengthen America's capabilities and capacity for revolutionary microelectronics design, architecture, and fabrication, as well as high-performance computing. New discoveries will enable the nation to overcome crucial scientific barriers for emerging technologies such as artificial intelligence, quantum technologies, and interconnected autonomous systems, and they will strengthen U.S. scientific leadership, economic prosperity, and national security.

MAJOR RESEARCH EQUIPMENT AND FACILITIES CONSTRUCTION

The FY 2020 Request includes funding to continue construction on two projects: the Large Synoptic Survey Telescope (LSST) and the Antarctic Infrastructure Modernization for Science (AIMS). Funding is also proposed for two detector upgrades to operate at the High Luminosity-Large Hadron Collider (HL-LHC).

The Large Synoptic Survey Telescope

The LSST will be an 8-meter-class wide-field optical telescope capable of carrying out surveys of nearly half of the sky. It will collect nearly 40 terabytes of multi-color imaging data every night to produce the deepest, widest-field sky image ever. It will also issue alerts for moving and transient objects within 60 seconds of their discovery. The FY 2020 **request of $46.3** million represents year seven of its nine-year construction funding profile.

The Antarctic Infrastructure Modernization for Science

In FY 2020 **NSF requests $97.9 million** to continue to invest in the AIMS project, a necessity for maintaining U.S. scientific and geopolitical eminence across the continent of Antarctica. The AIMS project is the primary component of the McMurdo Station Master Plan, with a specific focus on the core elements of this critical logistics hub. AIMS will enable faster, more streamlined logistical and science support by co-locating or consolidating warehousing, skilled trades work, and field science support.

High Luminosity-Large Hadron Collider

The LHC is the world's largest and highest energy particle accelerator. Located near Geneva, Switzerland and operated by the European Organization for Nuclear Research (CERN), the LHC can accelerate and collide counter-propagating bunches of protons at a total energy of 14 tera-electron volts. A Toroidal LHC ApparatuS (ATLAS) and Compact Muon Solenoid (CMS) are two general purpose detectors used by researchers to observe these collisions and analyze their characteristics. In FY 2020, an investment of **$33.0 million is requested** to begin upgrades of components of the ATLAS and CMS detectors that will enable them to function at much higher

collision rates following an upgrade to the LHC to increase its luminosity. FY 2020 funding would represent year one of a five-year project.

Mid-scale Research Infrastructure

The Mid-scale Research Infrastructure project, an effort that will address a gap between small existing research infrastructure instrumentation and existing large facility funding, has a new, dedicated funding line in the MREFC account for which **$45.0 million is requested in FY 2020**. NSF will implement a high-priority, agency-wide mechanism that includes upgrades to major facilities as well as stand-alone projects, such that research infrastructure investments above $20 million are managed as a portfolio. Individual projects will be selected through a dedicated program solicitation developed in FY 2019 and NSF's merit review process.

Daniel K. Inouye Solar Telescope and the Regional Class Research Vessels

NSF will continue to manage the construction of both the Daniel K. Inouye Solar Telescope (DKIST) and the Regional Class Research Vessels (RCRV) in FY 2020. FY 2019 represented the final year of funding for DKIST within an 11-year funding profile and completion of construction is planned for no later than June 2020. The FY 2019 appropriations for RCRV of $127.1 will complete construction of three vessels. The RCRV project will help to satisfy the anticipated ocean science requirements for the Nation. The vessels are a major component in the plan for modernizing the U.S. Academic Research Fleet. Construction of three ships to support the anticipated demands for coastal oceanography in the Gulf of Mexico and the East and West coasts will minimize transits and maximize research time in each of these regions. NSF plans to fund the operations of three RCRVs without increasing current annual costs, which is a result of fleet right-sizing and modernization.

EDUCATION AND STEM WORKFORCE

At NSF, our education activities are integrated with science and engineering, research and innovation. We recognize that combining the best that we know from research about learning and cognition with exciting opportunities to learn STEM is a winning combination for helping to effectively inspire the next generation STEM skilled workforce.

NSF's education and STEM workforce investments are primarily housed in the Directorate for Education and Human Resources but represent agency-wide investments in the education of tomorrow's scientists, engineers, and educators. NSF is committed to the education and training of a workforce for the 21st century economy. This workforce must be capable of adapting to the increasingly technical nature of work across all sectors. NSF works to prioritize programs that will provide experiential learning opportunities, as well as programs that prioritize computer science education and reskilling. Priority STEM education activities to prepare America's future workforce in FY 2020 are:

The Graduate Research Fellowship Program

The Graduate Research Fellowship Program (GRFP) recognizes students with high potential in STEM research and innovation and provides support for them to pursue research across all science and engineering disciplines. GRFP fellows may participate in Graduate Research Opportunities Worldwide (GROW), which provides opportunities to conduct research with international partner countries and organizations, and Graduate Research Internship Program (GRIP), which provides professional development through research internships at federal agencies. The GRFP program

will continue to align awards with NSF research priorities such as Big Data, AI, QIS, and NSF's 10 Big Ideas. In FY 2020, **NSF will invest $256.9 million in GRFP** and support 1,600 new fellows.

Improving Undergraduate STEM Education

In FY 2020, **$93.1 million** is requested for the Improving Undergraduate STEM Education (IUSE) initiative, which supports the development of the STEM and STEM-capable workforce by investing in the improvement of undergraduate STEM education, with a focus on attracting and retaining students and on degree completion. The initiative funds the development and implementation and the related research and assessment of effectiveness. Directorates across NSF invest in this program to support the development of a workforce that will be able to handle the real-world challenges of a STEM career.

Advanced Technological Education

In FY 2020, **$75.0 million** is requested for the Advanced Technological Education (ATE) program, which focuses on the education of technicians for the high-technology fields that drive our nation's economy. The program involves partnerships between academic institutions and industry to promote improvement in the education of science and engineering technicians at the undergraduate and secondary institution school levels. The ATE program supports curriculum development; professional development of college faculty and secondary school teachers; career pathways; and other activities.

CyberCorps®: Scholarship for Service

In FY 2020, **$55.1 million** is requested for The CyberCorps®: Scholarship for Service (SFS) program, which supports cybersecurity education at higher education institutions. SFS also focuses on workforce development by increasing the number of qualified students entering the fields of information assurance and cybersecurity, which enhances the capacity of the U.S. higher education enterprise to continue to produce professionals in these fields to secure the Nation's cyberinfrastructure.

Robert Noyce Teacher Scholarship

In FY 2020, **$47.0 million** is requested for the Robert Noyce Teacher Scholarship program, which seeks to encourage talented STEM majors and professionals to become K-12 mathematics and science teachers through funding provided to institutions of higher education towards scholarships, stipends, and programmatic support.

Louis Stokes Alliance for Minority Participation

In FY 2020, **$46.0 million** is requested for The Louis Stokes Alliance for Minority Participation (LSAMP) program, which assists universities and colleges in diversifying the nation's STEM workforce by increasing the number of STEM baccalaureate and graduate degrees awarded to populations historically underrepresented in these disciplines.

Computer Science for All

In FY 2020, **$20.0 million** is requested for Computer Science for All (CSforAll) to build on ongoing efforts to enable rigorous and engaging computer science education in schools across the Nation, to prepare the STEM workforce of the future. CSforAll aims to provide high school teachers with the preparation, professional development, and ongoing support that they need to

teach rigorous computer science courses and to give preK-8 teachers the instructional materials and preparation they need to integrate computer science and computational thinking into their teaching.

ADVANCE

In FY 2020, **$18.0 million** is requested for the NSF ADVANCE program, which increases representation and advancement of women in academic science and engineering careers, thereby contributing to the development of a more diverse science and engineering workforce. ADVANCE is an integral part of the NSF's multifaceted strategy to broaden participation in the STEM workforce and supports the critical role of the Foundation in advancing the status of women in academic science and engineering.

Hispanic Serving Institutions

In FY 2020, **$15.0 million** is requested for the Hispanic Serving Intuitions (HSIs) program to continue to enhance the quality of undergraduate STEM education at HSIs and to increase retention and graduation rates of undergraduate students pursuing degrees in STEM at HSIs. In addition, the HSI Program seeks to build capacity in undergraduate STEM education at HSIs that typically do not receive high levels of NSF grant funding.

Historically Black Colleges and Universities Excellence in Research

In FY 2020, **$10.0 million** is requested for the Historically Black Colleges and Universities Excellence in Research (HBCU-EiR) program to support projects that enable STEM and STEM education faculty to further develop research capacity at HBCUs and to conduct research.

CONCLUSION

The FY 2020 President's Budget Request for NSF represents a $7.066 billion investment in strengthening the nation's economy, security and global leadership through research in cutting-edge science and engineering and investments in STEM education and the future workforce. At this proposed level of funding, NSF would continue its work supporting research that advances national priorities such as growth in manufacturing, defense, and cybersecurity.

Over 50 percent of America's economic growth of the past 50 years is attributable to technological innovation. This innovation depends on significant investment in basic research. NSF had a role in the development of important advances such as the Internet, 3-D printing, and cell phones, and in responding to national and international crises. Since its creation by Congress in 1950, some 236 Nobel Prize winners have, at some point in their careers, been supported by NSF.

The discoveries and innovations funded by NSF have a long record of improving lives and meeting national needs. With the support of this Committee and the Congress, NSF will continue to invest in the fundamental research and the talented people – the discoveries and the discoverers – who improve our daily lives and transform our future.

Thank you for the opportunity to testify today and for your continued support of NSF. I will be pleased to answer any questions you may have.

Dr. France A. Córdova
Director
National Science Foundation

France A. Córdova is an astrophysicist and the 14th director of the National Science Foundation (NSF), the only government agency charged with advancing all fields of scientific discovery, technological innovation, and science, technology, engineering and mathematics (STEM) education. NSF is an $8.1 billion independent federal agency; its programs and initiatives keep the United States at the forefront of science and engineering, empower future generations of scientists and engineers, and foster U.S. prosperity and global leadership.

Córdova is president emerita of Purdue University, and chancellor emerita of the University of California, Riverside, where she was a distinguished professor of physics and astronomy. Córdova was the vice chancellor for research and professor of physics at the University of California, Santa Barbara.

Previously, Córdova served as NASA's chief scientist. Prior to joining NASA, she was on the faculty of the Pennsylvania State University where she headed the department of astronomy and astrophysics. Córdova was also deputy group leader in the Earth and space sciences division at Los Alamos National Laboratory. She received her Bachelor of Arts degree from Stanford University and her doctorate in physics from the California Institute of Technology.

More recently, Córdova served as chair of the Board of Regents of the Smithsonian Institution and on the board of trustees of Mayo Clinic. She also served as a member of the National Science Board (NSB), where she chaired the Committee on Strategy and Budget. As NSF director, she is an ex officio member of the NSB.

Córdova's scientific contributions have been in the areas of observational and experimental astrophysics, multi-spectral research on x-ray and gamma ray sources and space-borne instrumentation. She has published more than 150 scientific papers. She has been awarded several honorary doctorates, including ones from Purdue and Duke Universities. She is a recipient of NASA's highest honor, the Distinguished Service Medal, and was recognized as a Kilby Laureate. The Kilby International Awards recognize extraordinary individuals who have made "significant contributions to society through science, technology, innovation, invention and education." Córdova was elected to the American Academy of Arts and Sciences and is a National Associate of the National Academies. She is also a fellow of the American Association for the Advancement of Science (AAAS) and the Association for Women in Science (AWIS).

Córdova is married to Christian J. Foster, a science educator, and they have two adult children.

Chairwoman STEVENS. Fabulous. And at this time, we will now recognize Dr. Souvaine for 5 minutes.

TESTIMONY OF DR. DIANE SOUVAINE, CHAIR, NATIONAL SCIENCE BOARD

Dr. SOUVAINE. Chairwoman Stevens, Ranking Member Baird, Chairwoman Johnson, and Ranking Member Lucas, thank you for this opportunity to be with you here today.

Let me say first that I greatly appreciate the longstanding bipartisan support Congress and this Committee in particular has shown for NSF. We thank you for our Fiscal Year 2019 appropriation, which exceeds $8 billion for the first time.

The Federal Government is uniquely able to invest in fundamental research that drives innovation, impacting everything from national security to economic growth to education. The wisdom of Congress to sustain NSF funding levels despite competing priorities has helped ensure America has the new discoveries and technologies necessary for our security and prosperity.

I am confident that NSF will continue to manage its portfolio and do great things at the $7.1 billion level of the Fiscal Year 2020 request, and yet the NSB sees vastly more potential. In my written testimony I note that in Fiscal Year 2017 NSF could not fund $1.6 billion worth of outstanding merit-review proposals. Are we already losing out on the next Google, the next LIGO, or the next Kevlar? How many budding researchers might see a foreign talent program as the only option for pursuing the research that they love? I think all of us would rather see these discoveries blossom into new innovations here in the United States.

Last year, my predecessor testified that China is overtaking us in R&D investments. While science is the endless frontier, we are not the only explorers. If the United States is to maintain its standing as a global leader in science and engineering, we need a renewed national commitment to fundamental research.

I believe that this must include four components: First, money. After more than a decade on the board, I believe that NSF's budget needs an out-of-cycle adjustment. In this century it has not kept up with economic growth even as the economy has become more dependent on knowledge and technology-intensive industries. The proposed budget is a $1 billion cut. This would meet even more great ideas left on the table for others to find and make it increasingly hard for American scientists and engineers to be the vanguard of science and engineering infrastructure.

Dr. Córdova and her team have done an exceptional job of preserving balance and continuing to chart a course for impactful science that serves this country. But my 30 years of experience as a computer scientist and more than a decade on the board has left me with one conclusion. We are eating our seed corn.

Second, we need a long-term strategy. OSTP Director Kelvin Droegemeier has called for a holistic assessment of the Nation's science and engineering enterprise to help match our strategic priorities with our investments. I think this is a good idea, and I hope that will jumpstart a broader conversation about the challenges and opportunities facing our country in science and engineering.

For its part, NSF has already started to think in new ways. Under the leadership of Doctor Córdova, NSF has identified 10 Big Ideas, including preparing the future of work in a world with AI. Harnessing the data revolution is equally important. The board agrees that gathering researchers from across disciplines to tackle timely challenges will ensure that the agency's impact exceeds the sum of its parts.

Our strategy must include a commitment to ensuring that America has a STEM-capable workforce. We need to draw on the abilities and creativity of all of our citizens. This means improving and broadening STEM education and providing the problem-solving skills required in a job market often driven by advances in science and engineering.

Third, values. To remain a leader, global leader in S&E, we need to recognize that America has not led with dollars alone. We also lead by showing the world what a healthy research environment looks like. We should embrace American traditions of exploration, risk-taking, openness, and transparency. We should have no tolerance for sexual harassment or fraud. We should aspire to remain the shining beacon on the hill that invites the best minds from around the world to come here and perform research and innovate.

This does not mean naivete. We must protect our national security. NSB applauds efforts taken and steps taken by NSF and others to ensure and enforce existing conflict policies and enhance awareness of security concerns at universities. But our national security depends strongly on our leadership in science and engineering, which in turn is built on fundamental research and the free exchange of ideas.

Fourth, inspiration. We need the support of many leaders, including you, to inspire the next generation to be curious and to build the future. My generation was inspired by President Kennedy's call to explore the next frontier. Now excitement arises from new technologies and competition everywhere we look. It is on us to convey our appreciation and our understanding of the opportunities in science and engineering to back up that voice with a strategy and a sustained commitment to say to our citizens and to the world great ideas are born here.

I thank you for your time and look forward to your questions.

[The prepared statement of Dr. Souvaine follows:]

Testimony of
Diane Souvaine, PhD
Chair
National Science Board
National Science Foundation

Before the
Subcommittee on Research and Technology
Committee on Science, Space, and Technology
U.S. House of Representatives

May 8, 2019

"A Review of the National Science Foundation FY 2020 Budget Request"

A Celebration of Science

"The activity of science being necessarily performed with the passion of hope, it is poetical."
– Samuel Taylor Coleridge, letter to chemist Humphry Davy

The race to the Moon, the invention of the internet, the sequencing of the human genome, the quest to observe gravitational waves, the ambition to take a picture of a black hole – these scientific and engineering pursuits have revolutionized our understanding of the universe, our world, and ourselves. We know that all of these big projects are great achievements – but as scientists, as explorers, as innovators, we also know that they are milestones, not endpoints. They each spawned whole new avenues of discovery research, innovation, and invention.

Bold, inspirational, question-driven science and engineering projects like these are built on the bedrock disciplinary research that is a core of the National Science Foundation's mission. At the same time, such breathtakingly ambitious projects bring together researchers from across disciplines, challenging them to do something entirely new through a creative collision of ideas and expertise. In the process, we push the frontiers of science and engineering (S&E), producing new knowledge and new technologies that in turn spur new disciplinary and interdisciplinary research, fueling a powerful circle of curiosity, effort, and achievement. Only the federal government can ignite such endeavors, because they require a strategic long-term commitment to ideas with enormous potential – and the freedom to fail. Yet history has shown that taking these risks has paid off time and time again, with all sectors of our "knowledge ecosystem" – universities, government laboratories, industry – contributing to and benefiting from these visionary projects.

The 2017 Nobel Prize-winning discovery of gravitational waves is a recent example of a project that required long-term strategic planning and a commitment to patient investment. We often think of the Laser Interferometer Gravitational-Wave Observatory (LIGO) as a physics or astrophysics breakthrough. In reality it succeeded by drawing on many fundamental disciplines: not only physics, astronomy, and math, but also computer science, engineering, and materials research. LIGO moved from the realm of theory to research and development to construction only because the researchers developed and leveraged new technologies that made what was previously impossible possible. And this was an all-hands-on-deck project for the science, technology, engineering, and math (STEM) workforce, from PhD research scientists to expert engineers to skilled technical workers and skilled craftsmen who built and continue to maintain the instruments, particulate controls, and ultra-high vacuum equipment.

The lesson I take from LIGO, the Moon landing, the invention of the internet, and the Human Genome Project is that government leadership and willingness to take risks lets us do, create, and discover things that would have remained undone, unmade, and undiscovered without taxpayer investment. And when our scientific and elected leaders convey a spirit of adventure and excitement and belief in the national importance of this work, they inspire people to join these projects and students to see the wonder of STEM.

It would be easy to look at the triumphs of the last century and conclude that the best discoveries and innovations are in the rear-view mirror. I draw the opposite conclusion. By building on that knowledge and technology we can ask and answer questions that were in the realm of idle speculation even a decade ago. CRISPRs, AI, multi-messenger astronomy, genomics, big data, and quantum information systems are all right now opening broad new frontiers of science and engineering.

On top of that there are structural reasons to think that the best of science and engineering lies ahead of us. Before NSF was founded, S&E research was focused on using new discoveries to develop technologies used toward victory in World War II. In *Science - the Endless Frontier,* Vannevar Bush presented a vision for a new model, in which individuals with advanced degrees working at elite universities performed government-supported research. Since then, our national S&E ecosystem has changed and grown. Today, unlike at the turn of World War II, it involves many more actors, with differing motivations and expertise. Private corporations, non-profit foundations, many types of higher education institutions, including minority serving institutions, and federal agencies all fund activities with goals that are sometimes complementary, but also sometimes in competition with one another. In areas such as AI and quantum computing, all of these actors have their own reasons for pursuing the innovations that derive from fundamental research. The key is to not waste valuable resources on duplication of effort and to leverage the competitive advantages of our unique ecosystem. To this end the NSB supports OSTP Director Kelvin Droegemeier's idea to undertake a regular assessment of the status of the nation's R&D enterprise. In doing so, the federal agencies, including NSF, can more accurately identify opportunities and gaps in our nation's basic research portfolio.

The Board has also been thinking expansively about the future – about what we need to do now to enable the transformative research of tomorrow. As it has been almost 15 years since the NSB last published a vision for the future of fundamental S&E research, we are developing a *Vision 2030* to guide NSB actions and priorities over the next decade. While as Niels Bohr said, "It is very difficult to predict, especially the future," the exercise is an important part of strategic planning. International partnerships, collaboration and competition, research integrity, role of AI and big data, and the state of STEM education and the workforce rank high on the NSB's list of critical topics for exploration.

OSTP's proposed assessment, the Administration's five-year strategic plan for STEM education,[1] NSB's *Vision 2030,* NSF's 2022-2026 Strategic Plan, the NSF 2026 Idea Machine, and the work of this Committee will all help develop our strategy for this new era of discovery. We have an opportunity to demonstrate that the U.S. is determined to retain its position at the vanguard of science and innovation. To succeed in today's increasingly competitive, technological, knowledge-intensive world, we must celebrate our public commitment by renewing our support for the fundamental science and engineering that has been a core element of US security and prosperity in the last century. This commitment would entail strengthening our assets – a diverse, flexible STEM-capable workforce, state-of-the-art research facilities, world-class educational institutions, an innovative private sector, and forward-thinking policymakers – to help the nation prosper in the new global knowledge-intensive economy. And crucially, all of us – political leaders and S&E practitioners alike – must ensure that all Americans can participate in and benefit from advances in science and technology, and we must communicate clearly about the value of our S&E enterprise to the country and its citizens.

What do we need to do to enable transformative research?

> *"The great driver of scientific and technological innovation [in the last 600 years has been] the increase in our ability to reach out and exchange ideas with other people, and to borrow other people's hunches and combine them with our hunches and turn them into something new. ...Chance favors the connected mind."*
> – *Steven Johnson,* Where Good Ideas Come From: A Natural History of Innovation

Last year when my predecessor testified before this Committee, she highlighted that the 2018 *Science & Engineering Indicators* report confirmed a trend that we have observed for several years now: that while the U.S. remains a major global player in S&E, other countries have seen the benefits of investing in research and education and are following our example. The world of S&E, historically centered around the U.S., Western Europe, and Japan, is increasingly multipolar. Emerging economies, particularly of China and other countries in the Asia/Pacific region, are becoming major actors and near peers. These trends are expected to continue as more nations recognize that investments in research and development (R&D) translate into economic growth and create jobs. Congress recognized this and responded in FY 2019. The Board expresses its deep appreciation to Congress for demonstrating strong, bipartisan support for

[1] *Charting a Course for Success: America's Strategy for STEM Education.* The National Science and Technology Council, December 2018.

fundamental research. Now, as we look forward to FY 2020 and beyond, we ask: what does S&E leadership mean in this new context? What does it mean for U.S. S&E policy? In this competitive global landscape, what do we need to do now to continue to enable truly transformative research?

The answers are not easy, but the solutions are not unknown. There is no silver bullet, but there is wide agreement on many things. This Committee had an excellent hearing in March on U.S. leadership in science. All witnesses, again and again, echoed the same needs and the same themes. They highlighted the need for a strategy, a plan for prioritizing our focus and exploiting our many competitive advantages. We need predictable, sustained investment in the fundamental research that is intertwined with our nation's economic growth and we need to be cognizant of the investments of other nations who are trying to emulate our robust S&E ecosystem. We must diversify our STEM-capable workforce as, according to the Census Bureau, by 2042 our country will be a majority-minority nation. Thus, 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. This means improving 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 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.

What would a renewed national commitment to fundamental research look like?

Steady, predictable, federal funding for fundamental research commensurate with the growth of our knowledge-intensive economy.

In 1960, government spending on R&D was 1.69% of our GDP.[2] Today, that number has fallen to only about 0.7% as the economy has grown.[3] As we said last year when we came before this Committee, this is particularly challenging for our leadership in S&E. China is set to soon surpass us in gross R&D expenditures.[4] While business sector investment in R&D has recently grown faster than the government's, the lion's share of business sector investment has been on the applied side. The federal government provides almost half of all basic research funding, with the business sector providing 27%.

Within the realm of basic research, there are significant differences in the scope and time horizons of research funded by private business and that funded through federal agencies. Industry research often focuses on targeted goals likely to reap an acceptable return on the investment within a relatively short time horizon, or offer essential competitive advantages, for instance in AI. For early phase basic research it can take decades for a breakthrough to blossom into the next great innovation – and again: predictions are hard, if not impossible. The government is uniquely able to invest in curiosity-driven research over a long-time horizon.

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[2] National Science Board. *Science and Engineering Indicators 2014*, Appendix Table 4-1.
[3] National Science Board. *Science and Engineering Indicators 2018*, Figure 4.3.
[4] National Science Board. *Statement on Global Research and Development (R&D) Investments*. NSB-2018-9, 2018.

History has shown that such investments are an essential part of our innovation ecosystem, setting the stage for the directed research of the mission agencies and the private sector.

At NSF, things have changed significantly even in my time on the Board. As recently as 2000, NSF's funding rate for grant proposals was 33% (total submitted proposals: 29,508). In FY 2017, the funding rate was 21% (total submitted proposals 40,678). Going unfunded were $1.6 billion in proposals rated better than "Very Good."[5] Funding those grants is the difference between our current funding rates and the historical norm of ~30%. It is also the difference between a researcher's ability to secure funding to pursue promising ideas without excessive administrative burden in the form of constant proposal writing – and the search for a new career. Furthermore, individual investigator proposals are only one component of NSF's mandate to promote the progress of science. As described in two NSB reports to Congress in 2018, significant challenges exist in large facility operations and maintenance (O&M) and mid-scale research infrastructure.[6] While NSB applauds the initial response to those reports in the FY 2020 request, we remain mindful that we cannot hope to continue to be preeminent in S&E, and compete with the world's best, if we are leaving potentially game changing ideas on the table for others to find.

Development and implementation of a long-term strategy for our S&E enterprise.

As the participants in your March hearing on U.S. leadership in science articulated, 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, would help us match our strategic priorities with our investments. China has declared its intent compete in AI, quantum computing, and 5G wireless systems; NSB endorses the Administration's efforts, including in this Budget Request, to make the U.S. a leader in these areas. But this is only one part of a long-term committed strategy: many other things, including Congressional buy-in, private sector partnerships, and support for basic research are also essential for success.

For its part, NSF has identified ten Big Ideas as agency-level strategic priorities, detailed in the Budget Request. These Big Ideas include preparing for the Future of Work in a world with AI, Harnessing the Data Revolution, and the Quantum Leap, an investment exploiting quantum interactions to produce novel materials and next-generation information technologies. These are in coordination – not competition – with our disciplinary investments, ensuring that NSF welcomes the best ideas of scientists and engineers *and* that the agency is more than the sum of its parts. The Big Ideas and our new Convergence Accelerators build from disciplinary bedrock to tackle new questions and discovery spaces that are inherently transdisciplinary. They focus on frontiers where we need to draw on expertise from the disciplines and bring researchers together in new ways. In turn, the insights gained from these interdisciplinary efforts feed new ideas, tools, and techniques back into the core disciplinary research. As scientists and engineers in the

[5] Report to the National Science Board on NSF's Merit Review Process, Fiscal Year 2017, preliminary draft.
[6] National Science Board. *Study of Operations and Maintenance Costs for NSF Facilities* and *Bridging the Gap: Building a Sustained Approach to Mid-scale Research Infrastructure and Cyberinfrastructure at NSF*. 2018.

"innovation agency," the NSB commends Director Córdova for experimenting with our own structures, and not being risk averse.

NSF has long sought a balanced portfolio, one that recognizes and embraces the knowledge that transformational discoveries often grow out of repeated "dead-ends." The only real failure in research is when you stop learning. Our portfolio, and this Request, 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. Affording them the time and space to think creatively and experiment – including by reducing administrative burdens – is just as important for long-term success as the marquee discoveries that captivate and delight us all.

This Request also balances a robust portfolio of facilities and infrastructure at multiple scales with awards to the researchers who depend on the observations and data they produce. The challenge for our long-term strategy is to balance the facilities that we use today with the need for new cutting-edge facilities to further our knowledge tomorrow. We know that investment in scientific infrastructure at all scales is essential to U.S. competitiveness in S&E – but we also know that the cost of frontier-busting facilities will continue to increase. This will place a premium on balancing not only the portfolio mix between existing and new facilities, but also the balance between unilateral and partnership funding models. These issues became very clear in NSB's 2018 research infrastructure-related reports to Congress. As the agency engages in strategic planning for its facilities portfolio, NSB and NSF are working together to ensure that NSF is positioned to provide the future research infrastructure needs of the U.S. scientific community for decades to come. For all of these efforts, NSB has been working closely with the Chief Officer for Research Facilities – a partnership that has proved to be invaluable. The Board thanks Congress for recognizing the need for this position and creating it in the American Innovation and Competitiveness Act (AICA).

To continue the great legacy of American innovation and fulfill the potential to reach even greater heights, any successful long-term strategy must include a commitment to develop the domestic human capital that exists in every classroom across the country. STEM education across all demographic groups and geographic regions, beginning in primary school and continuing across all levels of education, is essential to the maintenance of economic prosperity in an ever-increasingly technological world. Ensuring that all Americans are STEM-capable 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. For its part, NSF has embraced this challenge through numerous programs, including one of its Big Ideas, NSF 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.

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 a NSB priority for several years. In our 2015 report, *Revisiting the STEM Workforce*,[7] we focused on "big picture" concepts including the breadth of the STEM workforce, the existence of multiple segments within the workforce each with its own story, and the fact that STEM knowledge and skills enable multiple, dynamic career pathways. The Board's 2018 policy brief, *Our Nation's Future Competitiveness Relies on Building a STEM-Capable U.S. Workforce*,[8] expanded on these themes and placed additional emphasis on the skilled technical workforce (STW) and on the need to attract demographic groups historically underrepresented in STEM. We have complemented these broadly-themed reports with more detailed examination of segments of the STEM-capable workforce, as we did with our 2017 statement and infographic, *SEH Doctorates in the Workforce*,[9] that focused on the career trajectories of S&E doctoral holders. The next installment in the Board's examination of the nation's S&E workforce is our forthcoming report on the Skilled Technical Workforce. We hope that this report, which is based on 18 months of NSB activities and stakeholder engagement, will complement and inform the recent work on the STW of both Congress and the Administration, in the context of our national conversation about preparing American workers for the jobs of today and tomorrow.

Leading the way in developing and implementing policies to strengthen our national scientific enterprise by improving its practice.

As the participants in your March hearing testified, maintaining S&E leadership is simultaneously becoming more challenging and more critical. In many ways, we need to rethink what "leadership" means. If we continue to rely only on historical "by the numbers" measures such as amount invested in R&D, number of STEM doctorates produced, and the number of scientific articles published, we will lose. As the Board noted last year based on data from *Science and Engineering Indicators 2018,* we are at a pivotal moment in our history as other nations, including China, invest more, aggressively compete for talent, and aspire to define the future of science and engineering.

At the same time, scientific practice and norms are evolving due to new concerns from within – the research community – and without – the new global landscape. We have an opportunity to define leadership as something more than a "numbers game" – to make it about *values*. To begin with, we must embrace our traditions of openness and transparency that have drawn the world's best to our universities and laboratories for decades and continue to show why the land of the free remains the gold standard for fostering intellectual curiosity and research collaboration. This does not mean naivete – we need to protect our national security. The Board strongly affirms[10] the principle behind President Reagan's National Security Decision Directive 189: "our

[7] National Science Board. *Revisiting the STEM Workforce.* NSB-2015-10, 2015.
[8] National Science Board. *Our Nation's Future Competitiveness Relies on Building a STEM-Capable U.S. Workforce.* NSB-2018-7, 2018.
[9] National Science Board. *SEH Doctorates in the Workforce*. 2017.
[10] National Science Board. *Statement of the NSB on Security and Science.* NSB-2018-42, 2018.

leadership position in science and technology is an essential element in our economic and physical security. 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."

Foreign-born individuals have long been major contributors to our S&E enterprise – as of 2015, over half of our doctoral-level S&E workforce, and a majority of first-year, full-time S&E graduate students in the natural sciences and engineering are foreign-born.[11] At the same time, we must be aware that the world's best minds have choices today that did not exist as recently as 20 years ago in selecting a place to study, perform research, and innovate. Other nations are actively courting globally-mobile talent, sometimes aggressively enough to violate U.S. government policies. Even as we work to broaden and enlarge the pipeline for domestic talent, it is important to continue to encourage the influx of curious, creative, and ambitious young researchers from overseas. At the same time, we should work together with our universities and research laboratories to improve institutional and community awareness of security concerns, ensure adherence to conflict of interest and commitment policies, and strengthen and clarify the necessary security and reporting requirements.

Beyond the issue of openness and transparency, our researchers should aspire to the highest standards and our institutions should exemplify those values. We should strive for results that can be reproduced, demand zero tolerance for fabrication and theft of intellectual property, and cultivate a culture of scientific practice free from harassment and welcoming to all. NSF has led the way in demanding its grantees comply with standards against sexual harassment, and other federal agencies and organizations have begun to emulate the NSF model. NSF and its Inspector General actively enforce research integrity and grants management standards. The U.S., and NSF, can continue to lead the world by setting examples about the responsible conduct of research and by promoting a healthy research environment – in short, by exporting American values.

Inspire the next generation of researchers by speaking with one voice about the value of fundamental discovery research.

When the U.S. was faced with the challenge of Sputnik, Congress chartered this committee as the Committee on Science and Astronautics. Not long thereafter, President Kennedy boldly set a course for the Moon. This call, backed up by the necessary investment, was answered in less than a decade. It is that same sense of national purpose that we need today to remain a leader in the global S&E enterprise. This year we celebrate the 50th anniversary of humanity's first steps on a new world and make plans to return. Today, this journey is joined by myriad, diverse scientific and engineering challenges that also motivate us. Now opportunities, competition, and excitement arise from science and technological advances everywhere, in every field, in research and industry and academia and business.

[11] National Science Board. *Science and Engineering Indicators 2018*. NSB-2018-1, 2018.

Meeting today's challenges requires our national leaders in academia, government, and the private sector to speak together about the importance of fundamental research, reminding ourselves and our fellow citizens why science and engineering matters and about the endless benefits each and every one of us have gained from government investment in fundamental research across all fields. As a member of the NSB for over a decade, it has been my pleasure to witness the example this Committee has set in modeling the standard for bipartisan support in an area of national importance.

As scientists, as policymakers, we are constantly asking the question: how do we get more young people into STEM? Here is one answer: we *inspire* them. My generation was inspired by President Kennedy's quest for the next frontier. Americans are still inspired when their nation asks them to rise to the challenge of audacious goals, solve real problems, and make a difference in the world. Meeting this challenge can be done while learning and doing exciting things: exploring the universe, unlocking the mysteries of the genome, designing faster, safer airplanes, developing technologies to mitigate climate change, and feeding the world. We can call on the curiosity and passion of our citizens and of people from around the globe to help us build the future here, in the U.S. – if we are willing to speak with one voice to celebrate science and engineering, and to back that voice up with a clear commitment and a long-term strategy. We can say to our citizens and to the world: *great ideas are born here*.

NSB and the FY 2020 Request

> *"I am certain that after the dust of centuries has passed over our cities, we, too, will be remembered not for victories or defeats in battle or in politics, but for our contribution to the human spirit."*
> *– President John F. Kennedy*

The Board applauds Director Córdova and her team for their accomplishments during this budget-constrained time. NSF has balanced the various demands on its financial and human capital to chart a course for impactful science that serves the country. The Administration's FY 2020 budget request will enable NSF to make outstanding contributions to the national S&E enterprise.

NSB has been an active partner with NSF management as the Foundation has navigated the evolution of science and engineering over its 70-year history. The increase in the cost of research amid the years of modest budget growth since 2000 have placed a premium on strategic leadership. The need to balance the bottom-up priorities expressed by the science and engineering communities with the agency's strategic imperative is a necessity. The Board has endeavored to offer sound counsel and strategic guidance in recent years through its publication of reports on topics ranging from the STEM workforce to administrative burdens to large facility O&M to mid-scale research infrastructure investments.

Our current priorities include continuing to partner with the Director and her team – including the Chief Officer for Research Facilities – to finish addressing the issues raised in the 2018

reports on NSF's research infrastructure. As mentioned, we are concluding our examination of the Skilled Technical Workforce. We are also working with NSF to make significant improvements to the annual Merit Review Report, and to reimagine *Science and Engineering Indicators,* in order to make both of these reports more timely and accessible for stakeholders. Finally, NSB is drafting a *Vision 2030* to help us plan for the long-term future of fundamental science and engineering research at NSF and for the nation.

As I have previously stated, Director Córdova has charted an excellent course forward for NSF building the Big Ideas and highlighting the importance of convergent research, while fully committing to continued investments in individual investigators, disciplinary research, major research facilities, mid-scale infrastructure, and the latest research instrumentation. NSB looks forward to continuing to work with the Director and her team to realize the full potential of these innovations.

Thank you for the opportunity to testify today, and for your continued support of NSF. I will be pleased to answer any questions you may have.

Diane L. Souvaine

Biography

Computer Science and Mathematics
A.B. c.l., English & Mathematics, Harvard University
M.A.L.S., Mathematical Sciences, Dartmouth College
M.S.E., Electrical Engineering & Computer Science, Princeton University
M.A., Computer Science, Princeton University
Ph.D., Computer Science, Princeton University

Dr. Diane L. Souvaine, Professor of Computer Science and Adjunct Professor of Mathematics, has been a member of the Tufts University faculty since 1998. She served as Vice Provost for Research from 2012-2016, Senior Advisor to the Provost from 2016-2017, and Chair of the Department of Computer Science from 2002-2009.

Prior to Tufts, Dr. Souvaine was a member of the Rutgers University faculty for 12 years. During her tenure at Rutgers, she served for 2.5 years in the Directorate of NSF's Science and Technology Center for Discrete Mathematics and Theoretical Computer Science (DIMACS), a groundbreaking academic/industry collaboration of Princeton, Rutgers, Bell Labs and Bellcore. DIMACS is tasked with both the theoretical development of mathematics and computer science and their practical applications.

Dr. Souvaine's research contributions range from solving challenging problems in computational geometry to practical application across disciplines. Her work extended the results of straight-edged computational geometry into the curved world. Visibility, triangulations and geometric graphs represent another focus of Dr. Souvaine's research as does the application of computational geometry to statistics. Her research led to consulting engagements with corporations such as Exxon Chemical Research, IBM and Pfizer.

Elected Chair in 2018, Dr. Souvaine is in her second term on the National Science Board to which she was appointed in 2008 and 2014. She previously served as Vice Chair from 2016-2018, has chaired NSB's Committee on Strategy and Budget and its Committee on Programs and Plans, and served on its Committee on Audit and Oversight, all of which provide strategic direction, and oversight and guidance on NSF projects and programs.

In addition to her scientific and policy contributions, Dr. Souvaine is dedicated to increasing diversity and advancing women and underrepresented groups in mathematics, science, and engineering and works to enhance pre-college education in mathematics and computational thinking.

Dr. Souvaine is a Fellow of the American Association for the Advancement of Science (AAAS) and of the Association for Computing Machinery (ACM), and was a 2005-2006 Fellow of the Radcliffe Institute for Advanced Study. Among many other accomplishments, she was the recipient of the 2008 Lillian and Joseph Leibner Award for Outstanding Teaching and Mentoring.

Chairwoman STEVENS. Fabulous. At this time we will begin the questions, and the Chair will recognize herself for 5 minutes.

Dr. Souvaine, in 2017, the National Science Board created a Task Force on the Skilled Technical Workforce charged with making policy recommendations to support workers that use STEM knowledge and skills on the job without the need for a bachelor's degree if I have that right. Can you update us on the activities undertaken by the task force, and could you also expound on when we can expect to find a summary of its findings and recommendations?

Dr. SOUVAINE. Yes. The task force will be reporting out to the board in our board meeting next week and sharing a draft of the proposal—the proposed findings. We expect that the final report, with luck, is released at the end of June, and we would be happy to share those results earlier.

Our work is comprised of multiple components. We've had listening sessions around the country to listen to students, faculty, members of industry, members of administrations of community colleges over the course of the 18 months we've been working on this. We've also been doing a lot of data gathering, working with NCSES, so there are multiple facets to this.

Chairwoman STEVENS. And I applaud both your efforts to push the boundaries of scientific discovery through the Big Ideas and Convergence Accelerator. Dedicating funds for these efforts is clearly important, and it also certainly means tradeoffs with other programs supported by NSF, including core research programs and potentially, you know, troubling support for graduate and undergraduate education and training through the Graduate Research Fellowship Program and Research Experiences for Undergraduates, which NSF administers. Both programs would see a substantial cut if the current budget were enacted.

I'd like you both to address two questions. One, how does the agency balance support for convergent research with support for the core research programs; and, two, how important is it to provide research experiences to undergraduates and dedicated support to graduate students? How will the Big Ideas and other convergence efforts support education and training for these students?

Dr. CÓRDOVA. I'll start. Thank you for the question. The Big Ideas grew out of a desire to give a more strategic framework to NSF's ideas for what requires future investment. They all grew out of the core, and they'll eventually go back into the core.

For example, take the Quantum Leap. NSF has been funding quantum research for the past three decades, and in fact 31 Nobel Prize winners for their quantum research achievements have been funded by the National Science Foundation over the past 30 years. And so it's not new.

What is new is the emphasis on how important quantum, especially its marriage with information sciences, is to the future of the country to get going fast and to accelerate it. And this acceleration depends on a convergent approach, that we need the computational scientists, we need the physical scientists, we need the engineers all coming together in order to make progress even faster along this trajectory.

And you can take any of the Big Ideas—Rules of Life, for example, is integrated into all of the biological sciences. It's really what they're looking for. So how do you get from the genome and its environment to phenotype? And that's important for agriculture; it's important for all the science we do.

So in all of the Big Ideas we are clearly funding faculty and researchers and their students, and, yes, it is involving the young people who will be the leaders of the future in these big, strategically important areas for the country.

It's interesting to me that exactly 3 years ago we introduced the Big Ideas to the National Science Board, which said, "have Big Ideas." The board has embraced them and, in the meantime, we had a transition in administration. The new administration has taken them on with a passion: Artificial intelligence, quantum information science, advanced manufacturing, and the future of work. So it seems that NSF was prescient in taking those ideas out of the core and giving them much more significance because that's where our country is headed, and frankly, it's where the whole world is headed. There's some fierce competition in this idea space.

Dr. SOUVAINE. Briefly, we need to find the best ideas wherever they arise and be able to be driven bottom up. At the same time we need to foster great opportunities of both convergence across areas but strategic areas that are timely, so this is—I concur with what Dr. Córdova just said. I also think that we need—and we'll come back to this, I'm sure—a broader pipeline of people going into science and engineering at all different levels.

So for me the funding of undergraduate research is critical. This is what does the inspiring I was talking about and gets undergraduates to move forward. We need to be funding more graduate students from all backgrounds from across the country who want to come and study, and the fellowships are critical.

Chairwoman STEVENS. Well, we want to certainly continue to make sure that those opportunities and onramps for those opportunities are taking place here in the United States.

I'm over time, so with that, I'd like to recognize our Ranking Member, Mr. Baird, for 5 minutes of questions.

Mr. BAIRD. Thank you, Madam Chair.

Dr. Córdova, in December the President signed into law the *National Quantum Initiative Act*, and as you know from your tenure at Purdue University, it was one of the first institutions to establish a quantum research center and it's well-positioned to help advance these new initiatives. Could you update us on how NSF is responding to the new law and what opportunities will be there for institutions like Purdue to participate?

Dr. CÓRDOVA. Certainly, thank you. So a number of the agencies have been funding—especially NSF and NIST—quantum research for a long time. Other agencies are revving up like the Department of Energy. They're funding as well. We all came together with the Office of Science and Technology Policy to produce a strategic plan for quantum information sciences in particular, which has terrific opportunities in the area of computing, which will be a gamechanger for how we do anything that involves computations.

Congress, at the same time, passed this initiative so all of this was rolled out at the same time. The White House had a summit

at which agency heads like myself spoke, and we gathered researchers from Purdue and many universities around the country to talk about their efforts. We fund a number of centers, NSF does, around the country in quantum research in general, and we all talked about how to accelerate those efforts because it's so important and so competitive globally that we do so.

As far as the law goes, OSTP is coordinating this effort with all the agencies. There's a coordinating group that's been set up under the leadership of Jake Taylor. We are all coming together periodically to share what we're doing and to coordinate those efforts around the country.

NSF is funding a lot of new efforts and centers and activity. For example, one is a collection of about 15 universities to build the first fully functional quantum computer. There's just a lot of energy around this, and we're really glad that Congress is so enthusiastic about positioning the United States to be the global leader in this area.

Mr. BAIRD. I have another question, and maybe both of you can respond to this as well. Last week this Committee held a roundtable with Federal agencies focused on artificial intelligence and research, including NSF. Can you discuss what type of strategy you think is needed to maintain the U.S. leadership in the AI field?

Dr. CÓRDOVA. Our artificial intelligence, like quantum research, is just an extremely productive, vigorous area of research in all kinds of ways in the United States and globally.

I co-chair an entity called the Select Committee on Artificial Intelligence, together with the head of DARPA, for the Office of Science and Technology Policy. Again, it's a collection of agencies that come to discuss what we are doing and what we can do together to further position the United States.

The National Science Foundation is spending in this Fiscal Year 2020 budget alone about $492 million on artificial intelligence writ broadly, and that's a big investment for the size of our budget. We are collaborating with industry and foundations and others in several very important partnerships, for example, on the ethics, fairness, and bias in everything that surrounds AI to make sure we do it in the right way. We have a collaboration with a group called the Partnership in AI—which is about 50 industries and others that we're working with—and we are asking for proposals, and we will co-fund those proposals.

We're also working with Amazon. It's our first such partnership in which Amazon is providing $10 million and NSF $10 million over the next 3 years to ask for proposals from the scientific community writ broadly to deal with issues around artificial intelligence. As my colleague Dr. Souvaine said, our Future of Work Big Idea is really being done within the framework of how artificial intelligence will affect the future of work. That's not just the future of work in the factory. That's the future of work in the classroom for teachers ad how it will help them. It's the future of work in assisted living and in all places where people conduct their work.

Dr. SOUVAINE. I think that our funding and investment in artificial intelligence needs to be commensurate with our national goals and aspirations, and we need to think about that as we go forward.

Mr. BAIRD. Thank you. And, Dr. Souvaine, I noticed your analogy about eating our seed corn, and I'm out of time but maybe I'll have a chance to ask that question, what you meant by eating our seed corn. I think I understand. Thank you.

Chairwoman STEVENS. Excellent. At this time I'd like to recognize my colleague Ms. Sherrill for 5 minutes of questions.

Ms. SHERRILL. Well, thank you both for coming here today. I'd like to applaud the historical bipartisan support for the NSF of this Committee. But I couldn't agree more with Ranking Member Lucas that we need to do more to educate the American people on the benefits of research and the need for good research to keep our economy ahead.

But talking a bit about what you said, Dr. Souvaine, you kind of touched on this. Often, the transfer of knowledge and technology between countries can be mutually beneficial. Historically, we benefited even from scientific cooperation with our geopolitical adversaries. Our economic competitiveness and national security are threatened, however, when our Federal investments in R&D, especially in emerging technologies, are transferred to another country through coercion, theft, or espionage. The Inspector General recently highlighted the agency's response to the national security threat of foreign talent as an emerging management challenge.

What steps is NSF taking to ensure its research investments are protected from these threats? And you both—if you could both answer that.

Dr. SOUVAINE. I'll defer very soon to Dr. Córdova on that, but I think that we want to be good partners with all countries where we're good partners, and that requires some of the values that I was referring to earlier. Clearly, this country benefits substantively from all of the people from around the world who come here to do great science. We benefit from the great partnerships with scientists across the world. Fundamental research requires transparency and engagement, exchange of ideas, which then can blossom. We do have to protect things.

And as I referred to in my opening remarks, I think NSF is working hard with universities, and our board statement reiterated that universities must be on top of their conflict-of-interest and conflict-of-commitment policies and we need to be working harder to make sure those are always honored.

Dr. Córdova?

Dr. CÓRDOVA. Yes, Congresswoman, one of the crucial issues of our time is this balance between openness that has brought us so far intellectually as a country and given us so much and protecting research in the research environment.

I'll just mention four steps that the National Science Foundation is doing. About a year ago we changed the requirement for rotators. We have close to 200 rotators who come in from universities, and they're in positions from Program Officers to Assistant Directors. They provide great value. We changed the requirement to be consistent with the Federal requirement that they be U.S. citizens or applying for U.S. citizenship. We didn't have that requirement before. That's one thing.

Since 1978, we've required complete disclosure forms from all our applicants for research grants. We haven't been so good about the

requirements for what those disclosure forms should look like or monitoring, assessing, and auditing them. So we are tightening up our disclosure forms.

We're establishing an easily computer-read disclosure form. We call it a bio-bib because it has the bibliography and biography. It has all forms of support that the researcher could get either from here or from anywhere else—in a very clear format. It would be uniform so a person only has to do it once and then update it. Machines could easily read it and look for whatever was of interest there. So we think this will go a long way to streamlining and enhancing what we know about other forms of support that proposers can have.

We are asking an expert committee called the Jasons to do a risk assessment on research protection because we need to know. As we take more steps to protect the integrity of research, we need to be careful that we don't overdo something or underdo it. You really have to understand what the risks are out there, and these are all people with top security clearances. We'll have that piece of work done hopefully this summer.

And then finally, we're working with the National Academies of course, which has a lot of expert people on it. We'll have a meeting this Friday at the National Academies, an entire half-day on this subject and see where to go from here and talk about what is needed.

The important thing is 85 percent of our clients—our grantees—are universities. It's important that we engage the leadership of universities so that they are very aware of what's going on and that they're very much partners with us. And many universities—we mentioned Purdue earlier is an example of one that has really taken this very seriously—have security people there. But not all universities do, and so we're trying—we're working on that front as well.

Ms. SHERRILL. Well, thank you. My time is expired, but I hope you are—conversely, you know, also worried about overprotection, and it sounds like you're very aware of that as well. Thank you so much.

Chairwoman STEVENS. Thank you. At this time we'd like to recognize Mr. Lucas for 5 minutes of questioning.

Mr. LUCAS. Thank you, Chair. I couldn't help but, as Dr. Baird was pursuing his line of inquiry, think about, Dr. Córdova, one of those areas that I have great interest in, which of course is the National Science Foundation's Established Program to Stimulate Competitive Research, EPSCoR affectionately known to all of us, which aims to assist States and universities in rural areas, underserved areas. It was updated by Congress 2 years ago based on outside panel recommendations. Could you visit for a moment about how NSF is implementing these changes and making sure the program is best serving rural States, yes, like Oklahoma, too?

Dr. CÓRDOVA. We are very, very proud of the EPSCoR program—very pleased with its results. As you know, there have been graduates from the program, so it has done what it intended to do. There have been several of those States that have achieved more capacity to do more research, and so that's great. We are constantly

reviewing the program, tooling it up for more and better collaborations.

What I've seen over the last few years is that we've reached out to assimilate other NSF programs within the EPSCoR program, for example, artificial intelligence or quantum or STEM education, and made sure that the EPSCoR proposers had the opportunities to be in those areas as well. I think things are going very well in the EPSCoR program, and we certainly would like the feedback of any members.

I go out a lot to EPSCoR States and I just see the kinds of things they're achieving, and again, I'm very proud that Congress stood up that program.

Mr. LUCAS. Absolutely. Dr. Córdova, I share Chairwoman Johnson's concerns about a STEM-ready workforce, and it appears that many American companies are in desperate need of those kind of individuals, STEM-ready. You recently worked with the Administration on a new 5-year strategy for STEM education across the Federal Government. How will this plan help address those industry needs?

Dr. CÓRDOVA. Yes, in early December the White House office of OSTP rolled out the STEM education plan, and agencies all had a lot of fingerprints on it. I think it's just a great plan. It actually speaks to, among other things, the need for a diverse and inclusive workforce. There's a lot of emphasis on programs like our INCLUDES programs that is broadening participation that will help get us there.

And at the time of the rollout of the STEM education plan, we were pleased to report that five other agencies of the Federal Government, including NIH and NASA, NIST, USGS, were joining the INCLUDES program to broaden participation. I think STEM education is, of course, a great way to do that.

Other elements of the plan really articulate the need for a skilled technical workforce. As was mentioned in the earlier conversation, the Board and NSF are working very hard to increase the attention on the need for a skilled technical workforce.

I did mention in my opening remarks the Advanced Technological Education program, which we've had for 25-plus years at NSF. That is mostly in community colleges, and its whole focus is on skilling the workforce. The President has a special committee on the American worker, and that is very, very focused on reskilling and upskilling the workforce for the technical jobs of the future.

So I've seen in just the last few years a tremendous emphasis in that direction. I think our National Science Board has rightly pointed out that we should increase and even accelerate those efforts. In fact, one other thing I'd like to mention is we have a statistical agency at NSF called NCSES, the National Center for Science and Engineering Statistics. They have taken on a new effort to assess what is the current situation for skilled workers, how many do we have, where are they located, what do industries need for the future? Where are the gaps and all? So I think we're going to see a lot more emphasis on this as we go forward.

Mr. LUCAS. Dr. Souvaine, could you share for just a moment the board's perspective on this, too?

Dr. SOUVAINE. Certainly. I think that since September 2018 when we started our skilled technical workforce task force, I think we've been looking very hard at the issue of the needs of skilled technical workers across all levels. I can think of one of the listening sessions we did at Macomb Community College in Michigan where there were members of industry that were there that had many, many jobs available open at the EDK level or higher but didn't have the right applicants to be able to fill them.

And this partnership, which came through an ATE program funded by NSF together with the local industry, together with the local community colleges, more than just Macomb, were doing something about drawing students in and trying to partner with them and have them learn the skills that they need with 2 years of training to be able to go on and enter these important jobs, maybe then going on later to a 4-year college or graduate school or something else, but entering the workforce and addressing this critical need.

Certainly, when we visited LIGO in Louisiana, we had the privilege of talking with David Barker there, who was responsible for the two-story HVAC system. And without this system, which is far more technically complex than an HVAC system was 10 years ago or 20 years ago, certainly the Nobel Prize winners would not have been able to get the Nobel Prize without that. There's a real—there is a real need there.

Mr. LUCAS. Thank you, Doctor. And thank you, Madam Chair.

Chairwoman STEVENS. At this time we'd like to now recognize Dr. Bill Foster for 5 minutes of questioning.

Mr. FOSTER. Thank you, Madam Chair, and thank you to our witnesses.

I'd like to speak a little bit about the issue with the Jasons that I believe you're familiar with. And for those of my colleagues who may not be, from I guess since the 1960s, the Jasons have been a group of very accomplished Nobel prize-winning-level scientists, mainly physicists, who provided confidential advice to the government, often very classified, very classified, so with everything from, you know, modern concerns like pit lifetimes or electronic warfare to I think back in the earlier years they provided an estimate or a second opinion to an Administration on whether or not it was a good idea to use nuclear weapons in Vietnam, which apparently the Administration at the time needed advice on.

And so it was a sort of shock to the scientific community a few weeks ago to learn that the Department of Defense had actually canceled the umbrella contract for the Jasons. And so this is a real source of concern because, you know, it's very often that those at agencies don't have the technical expertise particularly about speculative future technologies and need to be able to quietly ask a question that, you know, is this a concern, what are the possible things, you know, without having that, you know, become a source of, you know, public embarrassment if it turns out the question they're asking is—you know, sounds—could be made to sound, you know, not too sophisticated. And so, you know, I think the scientific community really values this as a communication channel.

And it's my understanding also that the National Science Foundation was specifically looking at contracting with the Jasons to

deal with this very tough problem that you're facing that, although the NSF has historically done non-classified research and published the results in the open literature, so many of the technologies now are dual use, you know, everything from biotech to artificial intelligence, you name it.

And so, first off, it's my understanding that there is a temporary fix to this, that instead of the Department of Defense canceling the budget, that it has been at least for this Fiscal Year transferred to the Department of Energy and NSA to keep the umbrella contract alive? Is that also——

Dr. CÓRDOVA. Our understanding is the Department of Energy, specifically NNSA, is looking to have a 9-month contract, that it is not fully completed yet. They're still in discussion. But we expect that that will happen, and that will get them through their summer studies. As you know, that's when they do their work because they have day jobs at universities.

And we had proposed a summer study on research protection on assessing the risk in this current climate of trying to make sure that our research has integrity and looking at the situation vis-a-vis other countries and seeing what steps the National Science Foundation should be taking in order to make sure the research is secure.

Mr. FOSTER. So at present you view at least the short term fix as adequate? Because, you know, one of the things that I think we're going to have to be working on in Congress is to make sure there's a long-term home for the funding here, that this is not something that gets, you know, jerked around and canceled and uncanceled continuously because the cancellation was only weeks before you had your kickoff with—my understanding, the kickoff meeting where these summer studies would have started.

Dr. CÓRDOVA. It is true that the Jasons have done a study for us in the past, and we could all use expert advice.

Mr. FOSTER. Yes. So if you see anything that changes where that is once again put at risk, please, you know, let Congress know quickly and make that request because this is important.

Now, in terms of the gist of what you'd ask the Jason to look at, and, Dr. Souvaine, you were quoted at a recent Science magazine article as being concerned about, you know, the policy implications of the fact that there are countries now targeting the United States for, I don't know whether you'd call it technology transfer or theft or whatever, and that, because of the dual-use nature of many NSF-sponsored technologies, is there anything you can say about your thinking on how we should respond to that?

Dr. SOUVAINE. I don't recall the exact reference you've raised, but certainly we are concerned about intellectual espionage, and NSF's OIG has found cases where this has happened. And—but as the board said in our formal statement last year, American technological preeminence is also critical for our economy and security, and we need to recognize that that's based on our leadership in fundamental research. And for that, creativity and collaboration and the free exchange of ideas are essential.

To paraphrase President Reagan's National Security Decision Directive 189, it's important that fundamental research remain unrestricted the maximum extent possible. So how do you balance that?

I think partly what Dr. Córdova was just talking about in terms of making sure that universities are putting the protections in place or reactivating them if they had slipped a little bit is important.

And they've adjusted, as she said, the rules for IPOs. It's also true that NSF's current proposal guide now has some changes in it like one is if a proposal includes funding to be provided to an international branch of a U.S. institution of higher education, including through use of subawards and consultant arrangements, the proposer must explain the benefits to the project of the performance done at that international branch campus and justify why the project activities cannot be performed at the U.S. campus.

So I think there's a real work in place at providing balance. I think, obviously, the Jason study is going to be very helpful in looking at next steps.

Mr. FOSTER. Yes. No, this is a tough issue that we're going to be grappling with for a while.

Dr. CÓRDOVA. For the record, I want to be sure just to clarify one thing. I think what Dr. Souvaine meant was that other agencies, specifically the NIH, have found instances of espionage. We have not at NSF. Definitely, we are working very closely with our Inspector General on this, and there are vulnerabilities, which is why we'd like to hire the Jasons to look at what are the risks, what are those vulnerabilities and understand them better.

Mr. FOSTER. Well, thank you. I appreciate your thoughtful, you know, work on this because it's a tough issue, and yield back.

Chairwoman STEVENS. At this time we'd like to recognize Mr. Marshall for 5 minutes of questioning.

Mr. MARSHALL. Yes, think you so much, Madam Chairwoman.

I'll start with Dr. Córdova. I'm a proud community college graduate, as well as a university undergraduate degree and a medical degree, so very proud of all those institutions in Kansas.

I know recently Seward County Community College told me they were doing some research funded, I believe, through NSF. Just kind of tell me what your vision is, how it's going. Has this been going on a long time using NSF funding at community colleges or where do you think it's going?

Dr. CÓRDOVA. We've been funding, for just over 25 years through our Advanced Technological Education program, community colleges. That's not the only program we have in community colleges of course. We are completely open to really good proposals and good ideas through our merit-review process. We then triage which are the best ideas, and we fund them. And they can come from wherever.

But we have a specific community college program called ATE, Advanced Technological Education. This has proven just a great program for students who might not want to have a 4-year degree or become a Ph.D. but want to go into the skilled technical workforce.

I've visited a couple of these, and I'm just so impressed by the facilities that they have and the enthusiasm of students, and they're getting a really, really fine education from the faculty. Faculty are just very, very committed to this kind of training.

We also have programs in STEM education which give research experiences for community college students to come, say, for the summer and work at a 4-year college. So it makes the transition, should they wish to go from community college to a 4-year institution, easier and smoother. They already know a laboratory and some faculty and so on.

Mr. MARSHALL. If you had never done this before within your department, what branch carries this out? Who would they contact?

Dr. CÓRDOVA. Oh, it's in Education and Human Resources, EHR.

Mr. MARSHALL. Right.

Dr. CÓRDOVA. They can contact me. That's what we have the forward button on our computers for.

Mr. MARSHALL. Well, I understand.

Dr. CÓRDOVA. I'll be happy to help.

Mr. MARSHALL. OK. I want to talk a little bit about your interaction with the private sector. I'm always concerned that we're doing research just for the sake of research, and I also believe within a system or goal, it's either getting better or worse. What are we doing to improve relationship with private industry and helping promote sharing the knowledge that we have for innovators to keep innovating?

Dr. CÓRDOVA. We have a lot of partnerships with industries at all levels. We have about 100 active partnerships and about another 100 under some form of discussion. Perhaps our biggest, most recent partnership, is with Boeing, and it's on two things. One is on upping online education in engineering. It's in the production realm, and it's how to increase access for people to get online education to up their engineering skills. Boeing is very interested in that, so they have given us $10 million, which we've matched with $10 million.

They gave us another $1 million for our INCLUDES program that I mentioned earlier, which is broadening participation. This is specifically for women to reenter the workforce after they've taken time off and they want to reenter the STEM engineering workforce.

Another partnership is with Amazon. That is on artificial intelligence and it's a 3-year program. Again, $10 million from Amazon and $10 million from us. It's to invite proposals that look at the ethical framework for artificial intelligence to make sure that we have, as Dr. Souvaine talked about earlier, our American values as we construct the infrastructure for artificial intelligence.

We have collaborations with Google, with all the big internet companies, and we have collaborations, of course, through our SBIR program, Small Business Innovative Research. We're funding a lot of really frontline research on all kinds of science and engineering projects.

Mr. MARSHALL. I want to try to jump in and get one more quick question in. The cost to do research per unit certainly I think would vary from place to place. How do you factor that in or do you at all?

Dr. CÓRDOVA. Yes. You mean when proposals come in?

Mr. MARSHALL. Right. I would just assume that research per unit would be cheaper at a place where the labor costs are less and the——

Dr. CÓRDOVA. Oh.

Mr. MARSHALL [continuing]. Electricity is less and some of those things.

Dr. CÓRDOVA. OK. I understand. So we have a merit-review system which is world-class. Other countries copy that. It has been refined over the 70 years that we've been around. That process looks at two things. It only looks at the budget later. It looks at intellectual merit, and it looks at broader impact. Then it gives a score for those two things and that's how we approve a proposal. Then we look at the budget and does it make sense. We review it in detail and we have lots of discussions with the proposers—can you do it for less or do you really think this is the right budget, and so forth. But it's only after considering those other aspects that we look at the budget.

Chairwoman STEVENS. At this time we'd—and thank you, Dr. Marshall.

At this time we'd like to recognize Dr. Lipinski for 5 minutes of questioning.

Mr. LIPINSKI. Thank you, Madam Chair. Dr. Córdova, Dr. Souvaine, thank you for your work. You both know how much I appreciate the NSF and the great work that the NSF does and the work that both of you do, so I've always been a very strong supporter of the NSF. And my questions are not going to be a surprise you what I'm going to ask about.

And the first is about I-Corps because I've been a big champion of I-Corps, Innovation Corps, since the NSF started it. I think it's really important that we do what we can to help get the great work—you know, turn to the great work that's being done through the research at our universities and also our national labs into new products and services.

So I'm pleased that the FY 2020 budget request indicates that NSF plans to expand I-Corps by increasing the number of sites and nodes, and fostering a national innovation network.

So my question is—and I know the overall budget is very difficult, you know, the small increase for I-Corps, but I wanted to know how you're going to balance the—Dr. Córdova, how you're going to balance the number of entrepreneur teams funded with new I-Corps sites and nodes if there is not a substantial funding increase.

Dr. CÓRDOVA. Thank you for your enthusiasm of our I-Corps. This is a program that's only about half a dozen years old, and it's already yielded over 500 new startup companies. And what it's really changed I think is the whole idea that faculty have that research can really be accelerated, and how do you do that acceleration? And so I think it's a culture changer, as well as given opportunities to new entrants to start their own businesses. When I've gone around universities, I've seen women and underrepresented minorities be some of the I-Corps participants who are then starting their own businesses. It's just a gamechanger.

We will do the best that we can by I-Corps. You've noticed that we've held the budget relatively flat even though we have $1 billion less in this proposal than we presently have to work with. But I-Corps—because it's worked so well in such a short time—has also influenced the way we do a number of our other programs. For example, our Convergence Accelerator has an I-Corps component to

it because it's all really about how do you get research to translate faster into public good. And I-Corps was a way that showed us how to do that.

Mr. LIPINSKI. Thank you. I wanted to move on to AI. Let me just say I appreciate the fact, as I said, that the budget is tough and the fact that I-Corps gets a small increase relative to everything else. I appreciate that commitment from the NSF to I-Corps and hope that continues to have that strong commitment.

I know that Ranking Member Baird talked a little bit about AI and asked a question about AI and social sciences. I have a bill right now that would coordinate AI R&D across agencies. And you know also the other thing I've been very focused on is social science research and the importance of social science research. I know you talked a little bit about that with regard to AI.

But one other aspect of that is what about the societal impacts of AI-enabled devices? Is this something that is going to be a focus of NSF-funded research?

Dr. CÓRDOVA. Absolutely. I mentioned a couple of new programs that we've offered or solicitations for proposals. One is the combination of the Social, Behavioral, and Economic Sciences Directorate with our Computer and Information Science and Engineering Directorate and an entity called the Partnership for AI, which is 50 industries and others. Together, they've pooled resources to ask for proposals in doing just that—to look at the ethical framework and the impact of AI on society, anything to do with AI and people and how it's going to affect them, but making sure that we have unbiased, transparent, fair approaches to artificial intelligence.

And one that's very similar is our collaboration with Amazon. This $20 million collaboration over the next 3 years where, again, it's the social and behavioral sciences and the computer and information sciences that are requesting proposals for ethical framework, impact framework for artificial intelligence. So I think we're going to see—we just welcome, as you know, all great proposals—and we'll see what we get. I'll be happy to report to you later what some of the more interesting proposals that we get along those lines.

Mr. LIPINSKI. Thank you. And, very quickly, Dr. Souvaine, do you have anything to add on either of those? You don't have to. I just wanted to give you the opportunity.

Dr. SOUVAINE. I think the board is very interested in looking at AI, and we had a plenary session last July about it. I think trustworthy AI is important, and we have to make sure that we're incorporating ethical and other kinds of social and behavioral questions into our development of AI.

Mr. LIPINSKI. Great. Thank you, and I yield back.

Chairwoman STEVENS. Thank you, Dr. Lipinski. And now I'd like to recognize my colleague from Ohio, Mr. Gonzalez, for 5 minutes of questioning.

Mr. GONZALEZ. Thank you, Madam Chair. Thank you to our witnesses not only for being here but for your incredible leadership in helping maintain our innovative edge in the United States.

I've been clear on this Committee from day one that I believe basic research is critical to our economic future, and I look forward to continuing to support NSF and all the great work that you do.

My biggest concern right now is that we're going to fund the programs—and I believe we will—but that we are still vulnerable to threats specifically from China. Just last month, FBI Director Christopher Wray pointed to the multilayered threat posed by China, went on to say that no country represents a more severe intelligence collection threat than China and that China has pioneered an approach to stealing our innovation from a wide array of businesses, universities, and organizations.

Dr. Córdova, you mentioned that NSF has not found any violations yet. I'm concerned, frankly, that means that we haven't looked hard enough because I just don't believe that China had—I've heard anecdotal stories, but that they are not actively trying to take our innovation. Can you speak a little bit more to that? How confident are you that, even though you haven't found anything, that it's not occurring?

Dr. CÓRDOVA. I'm not.

Mr. GONZALEZ. OK.

Dr. CÓRDOVA. And you're absolutely right. We actually have a new research protection group within NSF that's chaired by one of the people in my office. It's people across the whole agency to look at ways that we can tighten our procedures in order to mitigate against that.

We are working very closely with the Inspector General. They have their own people in charge in this area, and we're talking together about what we can do and how to approach this and where there might be vulnerabilities.

I mentioned earlier one of them is in the whole disclosure business. We do have, in theory, if everybody were disclosing properly——

Mr. GONZALEZ. Yes.

Dr. CÓRDOVA [continuing]. All their relationships. Then we would know how to tighten those procedures, too. So, yes, we're really working on it. And I also mentioned we'll have this meeting at the National Academies. We attend many FBI and CIA meetings, so we're on it. We just want to be careful, as we talked about earlier.

Mr. GONZALEZ. Yes.

Dr. CÓRDOVA.You just don't want to go overboard in one direction. You want to be sure that there's a balance there.

Mr. GONZALEZ. Absolutely.

Dr. CÓRDOVA. Sure.

Mr. GONZALEZ. And thank you. I don't mean to be quick with it——

Dr. CÓRDOVA. Sure.

Mr. GONZALEZ [continuing]. But I will say before I move on to my next question I look forward to working with everybody on the Committee and with both of you to make sure that we can strike that right balance. We can get this right, we absolutely can, and so I look forward to that.

Now I want to shift briefly to talent specifically in AI. I ran a technology company at one point in my life, and the value of an A-plus engineer versus a B engineer is actually 10X, 15X. I'm seeing the heads nod, so agreement there. I guess my question would be from a talent-management standpoint in NSF when the Googles and Facebooks of the world can pay pretty crazy sums to our engi-

neers, how are we competing for talent and making sure that our talent stays in the NSF or is working on the problems that we need them to work on specific to AI?

Dr. CÓRDOVA. We have this rotator program that I mentioned——

Mr. GONZALEZ. Yes.

Dr. CÓRDOVA [continuing]. Where we can bring people in. The majority of them come from universities. There's no reason why they can't come from industry as well and work with us and share. It is just an amazing program that we have with NSF.

Mr. GONZALEZ. To get it to industry, would that require a congressional fix or is that something within your purview to——

Dr. CÓRDOVA. No, it's within our purview.

Mr. GONZALEZ. OK.

Dr. CÓRDOVA. We of course, you know, just do the conflict of interest——

Mr. GONZALEZ. Right.

Dr. CÓRDOVA [continuing]. But, no, absolutely. And now, what we're seeing in universities is there's more churn there, too, with people coming from industry into universities, leaving for a while, teaching, et cetera, then going back to industry and so on. So I think the circulation of brain talent is going to happen more and more.

Mr. GONZALEZ. OK. Great. So the rotator program sounds like it'll be a big plus for us.

And then, Dr. Souvaine, I want to shift to something that you said when you're talking about American leadership. And I don't want to necessarily prime you, but another priority of mine is to make sure that we're promoting STEM for women in STEM. And you made a specific comment about having no tolerance for harassment, completely, 1,000 percent agree. How can we do a better job of making sure that we are fostering an environment that is more conducive to women in STEM?

Dr. SOUVAINE. It's complicated. I think we've been working at that for quite some time. I can think back to when I was a young researcher, coming to NSF was always wonderful because NSF got it early, and there were women in the building. In lots of places I went, there weren't any women in the building, so it was always pleasant to visit NSF.

And I think if we look at some statistics, it looks like we're not making much advancement on having women in science and engineering. And yet if you look at the numbers, the numbers are going up. It's just that the growth of the workforce in science and engineering is going up faster than the number of women.

I think we have to have a textured approach. I think we need to look at multi-facets. And part of that sometimes can also be looking at little things. I know this will sound maybe trivial, but I remember being on a faculty search committee and going to the first meeting where people said that they had already previewed the applications and they culled them down to just those that had the right number of publications in the top journals. I said that's wonderful. I'd love to redo the count. And they said, wait a minute, no, no, we know the top—I said you know the top journals but I'd

like to do it by page count, not on numbers of papers. And they said it's the same thing, the journals published.

I said no, it's not the same thing because often the woman or the person of color or the first-generation college goer will collate more results into one paper so that when they submit it, they have confidence it's going to be accepted, and they said I don't believe that, but we'll recount. We got back the next week, and there were five more women in the pool, one Native American and one African-American just by looking at the longer—and the journals aren't going to throw pages at somebody.

Mr. GONZALEZ. Yes.

Dr. SOUVAINE. We may need to have the passion that NSF has had to understand it's important to take steps to do things within the foundation, but we need universities, we need industry people, we need everyone to try to look at different biases that could also feed into the AI question we had earlier that might be not recognizing the talents of people that we are—actually have.

Mr. GONZALEZ. Great. Well, thank you. My time is up, but again, I just want to thank you both for your leadership. And one final comment. The little things add up, right, that make a big difference, and so I appreciate your sentiments, and thank you both for everything.

Chairwoman STEVENS. We were delighted to give Mr. Gonzalez some extra time for that fabulous last question.

And now I'd like to recognize my other colleague from Ohio, Mr. Balderson, for 5 minutes of questioning.

Mr. BALDERSON. Thank you, Madam Chair.

Dr. Córdova, thank you very much for being here this morning. And investing in basic research and education is crucial to ensuring America continues to be the world leader in scientific innovation, and the NSF plays a major role and central role in that.

One of my passions in Congress is ensuring that our workforce is prepared. The Advanced Technology Education program at NSF has got my interest. Could you talk a little bit about how ATE is preparing students for the 21st century economy and what sets the program apart from other CTE initiatives?

Dr. CÓRDOVA. CTE?

Mr. BALDERSON. Career and technical education, thank you.

Dr. CÓRDOVA. OK. Thank you. I'm very familiar with ATE and CTE caught me off guard. So the Advanced Technological Education program has been going on for over 25 years now. We love the program and so does Congress. It keeps increasing the budget for it. It is in many, many community colleges around the country, and it is giving students the opportunity to get training to be part of a skilled technical workforce. It doesn't require that they go on for a 4-year degree, and they are coming out with really great skills.

I visited some of these community colleges and have seen the kind of facilities that they have to train the students, talked with the faculty who are very educated about the industries of the future and what they need. What is really of interest to me is that every ATE in each community college is different because they're really serving the community. So if you have one in Indiana, one in Ohio, there will be different depending on the industry base of

the area. They're very much finely tuned so that people can get skills to go into those particular industries and more general skills as well.

So it's a great program, and it's just had terrific results. It's not the only thing we do for the skilled technical workforce. Actually, we're spending—depending on how you count the dollars because of all our programs—hundreds of millions of dollars on the skilled technical workforce because we have a lot of other entry opportunities. But that one is a great one.

Mr. BALDERSON. Thank you. Are there any thoughts or insights or ideas on how we could expand some of this into a rural district or rural area that's out there?

Dr. CÓRDOVA. Yes. We do have programs that are for more rural areas. They're usually in bigger collaborations where universities or community colleges want to penetrate those areas. We have programs for Native American communities that are generally in more rural areas. It kind of depends on what you mean by rural because we fund about 2,000 universities, colleges, and many other entities, and they can be in principle anywhere. So it really depends on exactly what the program is.

I know some of our INCLUDES programs, which broaden participation specifically, are designed to go into rural areas to try to have more STEM initiatives. Young people having access to STEM, can be inspired and then go on to colleges and so forth. I hope that's helpful. And we can get you more detail on specific rural programs.

Mr. BALDERSON. That was my next question if you could send that to me.

Dr. CÓRDOVA. Yes.

Mr. BALDERSON. Thank you very much. I appreciate that.

Madam Chair, I yield back my remaining time.

Chairwoman STEVENS. Excellent. Well, I think it's fair to say that we are in very good hands at the NSF with this leadership and from today's very important hearing, reviewing the Fiscal Year 2020 budget.

As the Representative from Michigan, I am delighted by the leadership from NSF in our State. Over $200 million of funding that our State has received, our top three research institutes, our universities, University of Michigan, Michigan State University, and Michigan Technological University receiving lots of support for basic research and efforts that have had profound implications for our State, particularly in STEM workforce training and supporting students and the next generation of discoverers.

So before we bring this hearing to a close, I'd just like to thank our witnesses for testifying before us here today.

The record is going to remain open for 2 weeks for additional statements from Members and any other questions that they might ask of you.

And at this time, our witnesses are excused, and the hearing is now adjourned.

[Whereupon, at 11:31 a.m., the Subcommittee was adjourned.]

Appendix I

Answers to Post-Hearing Questions

ANSWERS TO POST-HEARING QUESTIONS

Responses by Dr. France Córdova

UNITED STATES HOUSE OF REPRESENTATIVES
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY
Hearing on
A Review of the National Science Foundation FY 2020 Budget Request

May 8, 2019

Questions for the Record Submitted by Chairwoman Haley Stevens to

Dr. France Córdova,
Director
National Science Foundation

ACADEMIC RESEARCH FLEET (ARF)

Question 1. The budget documents state "NSF plans to fund the operations of the RCRVs without increasing overall fleet costs, which is a result of fleet right-sizing and modernization." How do the RCRVs fit within the existing NSF fleet of research vessels? What vessels, if any, is NSF divesting from to support the RCRVs?

Answer: The three RCRVs are NSF's contribution to sustaining and improving the U.S. Academic Research Fleet (ARF), which is currently comprised of 18 vessels operated by 14 institutions. The first RCRV, named *R/V Taani*, will be operated by Oregon State University (OSU) and will replace the NSF-owned *R/V Oceanus*, a 43-year old vessel nearing the end of her projected service life. The second RCRV, named *R/V Resolution*, will be operated by the East Coast Oceanographic Consortium led by the University of Rhode Island and will replace the NSF-owned *R/V Endeavor*, the 43-year old sister ship of the *R/V Oceanus.* The third RCRV is not yet named, nor is an operating institution identified. The ship will operate in the Gulf of Mexico and ensure continued support for oceanographic research following the expected retirement of the aging ARF vessel *R/V Pelican*, owned-operated by the Louisiana Marine Consortium. NSF Solicitation #19-573, which closes on July 1, 2019, invites proposals for operating the third RCRV. NSF expects to make an award in time to support operator participation during final design and construction.

Question: How will NSF ensure continued access to capabilities comparable to those currently provided by existing NSF marine research facilities such as the *RIV Marcus G. Langseth*?

Answer: NSF's Division of Ocean Sciences (OCE) continues to support a broad portfolio of marine seismic research using a wide range of seismic tools. Over the past four years, OCE has worked with the research community, the University-National Oceanographic Laboratory System (UNOLS), and other stakeholders to make progress on developing a new, financially sustainable seismic data acquisition strategy that implements the recommendation from the National Research Council's report *Sea Change: Decadal Survey of Ocean Sciences, 2015-2025* to divest from *R/V Marcus G. Langseth*.

As part of this strategy, NSF has sponsored workshops to address the scientific and technological drivers of the marine seismic community, established a Regional Framework Plan, surveyed the community for feedback regarding seismic research needs, and issued Dear Colleague Letters and solicitations. The most recent event was the April 1-3, 2019 "Future of Marine Seismics

Workshop" to identify and evaluate realistic models for providing access to the active source capability currently provided to the U.S. research community by the *R/V Marcus G. Langseth*.

Marine seismic research continues to be of significant value and importance to the marine geoscience community. As such, NSF continues to accept proposals that include data acquisition using capabilities similar to those provided by the *R/V Langseth* where access to these capabilities are coordinated by principal investigators (PIs), such as through industry providers or international/institutional partners.

NSF OCE is taking the following actions to ensure continued access to capabilities comparable with those available via the *R/V Langseth*:

1. Operations of *R/V Langseth* will be extended to the end of Fiscal Year 2021 (September 30, 2021) when dry-docking of the vessel would be scheduled. The dry-docking activity, which would be necessary for continued operations, will not be conducted and instead the vessel will be retired.
2. NSF is accepting proposals for use of the *R/V Langseth* during the period October 1, 2020 to September 30, 2021. The focus of this final year of vessel operations is on mentoring and providing opportunities for early career researchers to develop their skills, particularly as PIs.
3. NSF seeks to avoid a hiatus in seismic research opportunities after retirement of *R/V Langseth* by facilitating access to comparable capabilities available in the commercial and international sectors through two mechanisms, that are not mutually exclusive.
   a. NSF will solicit proposals for an award to establish a seismic vessel facilitator whose role will be to work with PIs in identifying potential commercial sector vessels with the needed seismic capabilities and developing contract documentation needed to support the submission of science proposals. It is expected that the facilitator will be in place before the retirement of the *R/V Langseth*.
   b. NSF will accept science proposals that use international vessels in parallel with proposals using commercial sector vessels.

National Center for Science and Engineering Statistics

Question 2. There are evolving demands for data from the National Center for Science and Engineering Statistics (NCSES), including interest in collecting data on STEM workers without advanced degrees and the nature and prevalence of sexual harassment in STEM studies and careers. The FY 2020 budget request includes a nearly $5 million, or 9 percent, cut to NCSES.

- **Can you talk about the current workload of NCSES and its capacity to expand the scope of that work to address emerging policy interests?**
- **What budget would be needed to allow NCSES to take on these new activities?**

Answer: NCSES - as a principal federal statistical agency - has a distinct mandate to fulfill, and NSF remains vigilant about NCSES' workload and funding levels. NCSES' activities include: its collaboration with the National Science Board's (NSB's) *Science and Engineering Indicators (SEI)*; collecting more data on emerging policy topics of critical interest and importance to the Nation's science and engineering (S&E) enterprise, such as the Skilled Technical Workforce (STW) and the prevalence of sexual harassment in STEM; and working to meet Federal statistical agency mandates to modernize data structures and systems, including increased use of administrative data to address the requirements of the Foundation of Evidence-Based Policy Act of 2018 (Public Law No: 115-435). One effort to better manage its workload and gain efficiencies is an update to or "reimagining" of the NSB's flagship Congressionally-mandated report, *SEI*. The goal is that the new model for *SEI*, beginning with the 2020 edition, be published as a series of

streamlined, focused reports rather than as one massive volume, allowing NCSES to better balance workload demands throughout the two-year *SEI* cycle, and better leverage the work performed across the suite of NCSES reports as input to *SEI*.

Major Facilities Construction Planning Projects

Question 3. With the completion this year of the Daniel K. Inouye Solar Telescope, and construction of the Large Synoptic Survey Telescope slated for completion in FY 2022 and the Antarctic Infrastructure Modernization for Science Project in FY 2023, it appears there will be a gap in major facilities construction at NSF by FY 2024. We looked back well over a decade and NSF has not had a gap in major facilities construction projects. What is on the horizon for major research facilities construction at NSF? What is the status of NSF' s planning for these facilities?

Answer: Should Congress appropriate funds for the Mid-scale Research Infrastructure portfolio that was proposed in the Major Research Equipment and Facilities Construction (MREFC) chapter of the FY 2020 Budget Request, NSF anticipates continuing that portfolio through FY 2024 and beyond. It is also likely that some of these mid-scale research infrastructure projects will pave the way (both scientifically and as engineering demonstrations) for future major facility projects.

The FY 2020 Budget Request also proposed a new construction start for the High Luminosity Large Hadron Collider, which is currently in its Final Design Phase, and has a budget profile that is expected to continue through FY 2024.

Since submitting the FY 2020 Budget Request to Congress, NSF has admitted the Leadership Class Computing Facility for entry into the MREFC Design Stage and will identify in future budget requests the Research and Related Activities funding required for this project to proceed through its Design Stage activities. The Leadership Class Computing Facility will soon begin the Conceptual Design Phase. If all goes well, it will progress through the Conceptual, Preliminary, and Final Design Phases and could potentially be included in a FY 2023 or FY 2024 MREFC budget request.

NSF typically has a number of major facility projects in the Development and Design Stages as they prepare for construction readiness and possible submission as new starts in the MREFC budget line. Not all potential development projects will proceed to budget requests, and no potential major facility construction projects will appear in an MREFC budget request until the National Science Board authorizes the Director to request funds. Thus, projects that would start in FY 2024 or FY 2025 will not be specified until those requests are submitted to Congress.

Some NSF directorates have been reluctant to propose new major facility projects to the NSF Design Stage because of the challenge of rapidly accommodating operations and maintenance (O&M) costs as facilities come on line. The Facility Operation and Transition funding requested within Integrated Activities in the FY 2020 Budget Request is a pilot program designed to allow the full O&M costs of newly constructed projects to be gradually absorbed by research directorates. This pilot program is an initial response to the recent National Science Board (NSB) "Study of Operations and Maintenance Costs for NSF Facilities" (NSB-2018-17), which recommended "incentivizing the development of new world-class facilities by allowing for partial, time-limited funding of initial O&M costs."

The National Academies of Science, Engineering, and Medicine are currently conducting their 2020 decadal survey in astronomy and astrophysics, which is scheduled to be released in the first half of 2021. Several candidate projects have received development funds or precursor funds from NSF. However, NSF does not intend to admit any of them to the formal Design Stage until after decadal survey prioritization, so that taxpayer resources are only spent on the highest community priorities. (As a past comparison, the Large Synoptic Survey Telescope was ranked first in the 2010 decadal survey and appeared in the NSF FY 2014 Budget Request.) Other potential projects outside of astronomy are in varying stages of development and may be part of NSF budget requests during the decade of the 2020s.

Questions for the Record Submitted by Daniel Lipinski

SOCIAL AND BEHAVIORAL SCIENCES

Question 1. I am a strong advocate for the social and behavioral sciences. Please describe promising areas of study in these sciences both within and outside of the Ten Big Ideas.

Answer: SBE-supported research holds great promise for addressing current and emerging challenges:

- The Opioid Epidemic: SBE-funded sociologist Dana Haynie is working with computer scientists to understand how illicit drug markets operate online and helping to highlight effective methods to shut-down the most successful suppliers. Cultural-anthropologist Lee Hoffer and colleagues are working with at-risk populations to develop interventions and help pregnant women improve outcomes for their children. Sociologist Elizabeth Chiarello is working with pharmacists and law enforcement to understand the different roles in policing this crisis and what effect that might have on the ability to act in the best interest of patients.
- Helping Returning Veterans: Michael Kahana's SBE-supported research has led to promising insights about the effects of traumatic brain injury (TBI) on memory formation. The Defense Advanced Research Projects Agency is now investing in this research in the hope that the basic findings can be turned into tools or interventions for the many veterans who are living with TBI. Gelsey Torres-Oveido studies interactions between brain and machine as she designs tools to help people relearn the ability to walk after brain injury and stroke. This advance could significantly improve how vets recover from injuries. SBE-supported psychologist John Cacioppo is credited with bringing the importance of loneliness to the attention of the military. The VA is now studying the role of loneliness in depression and suicidality and to intervene through primary care; and the Army is conducting a 5-year project to reduce feelings of isolation when troops return home.
- Broadening Participation in STEM: For America to remain the preeminent global force in science, engineering, and technology we need a strong workforce, one that harnesses the potential of all Americans. SBE supports investments in the Science of Broadening Participation for evidence-based research that provides answers to questions about what works to effectively broaden participation. For example, research by Jessica Good has shown that minority groups' feelings of inclusivity and their persistence in STEM (science, technology, engineering, and mathematics) increases when classroom philosophies support multiculturalism, and researchers such as Lise Vesterlund and Nilanjana Dasgupta have pointed to the importance of mentoring relationships to persistence in STEM.
- Measuring and Identifying Gaps in the STEM Workforce: Without evidence, we cannot build evidence-based policy. The National Center for Science and Engineering Statistics (NCSES) located within SBE, provides timely, accurate information to practitioners, researchers, policymakers, and the public on the science and engineering workforce and the conditions of the scientific enterprise in the U.S. and beyond. NCSES, the nation's leading provider of statistical data on the U.S. science and engineering (S&E) enterprise, is the source of information on the S&E workforce, investment in research and development (R&D), the condition and progress of STEM education, and U.S. competitiveness in science, engineering, technology, and R&D. The *Women, Minorities, and Persons with Disabilities in Science and Engineering* report[1] and the *Science and Engineering Indicators*[2] provide foundational knowledge about gaps in the U.S. STEM enterprise and guide steps for broadening participation. SBE-supported research can play a major role in improving the STEM workforce.

[1] https://ncses.nsf.gov/pubs/nsf19304/
[2] www.nsf.gov/statistics/2018/nsb20181/

SBE is playing an active role in eight of NSF's 10 Big Ideas. Specifically, SBE contributes to four of NSF's Research Big Ideas, as described below:

- The Future of Work at the Human-Technology Frontier: This Big Idea seeks to help society better understand, and more effectively build, the human-technology relationship in the context of work. Relevant activities include assessing the social and behavioral implications of automation; producing new technologies to augment human performance; developing and evaluating mechanisms to foster lifelong and pervasive learning with technology; and many more.
- Understanding the Rules of Life: Predicting Phenotype: This Big Idea seeks broad interdisciplinary approaches to understanding the regularities that guide or influence the emergence of observable characteristics; i.e., phenotype, in organisms across the tree of life, including humans. Studying human genetic variation, adaptation to extreme environments, and the epigenetic expression of the human genome has the potential to advance our understanding of human behavior, health, and well-being.
- Navigating the New Arctic: The Arctic is undergoing rapid biological, physical, and social change, not only its shape and surface properties, but also the ways in which humans can interact with it. This Big Idea seeks to improve our understanding, and more effectively adapt to how Arctic changes will influence communities both in the Arctic and beyond.
- Harnessing the Data Revolution for 21st Century Science and Engineering: This Big Idea encourages NSF's research community to pursue broad, interdisciplinary research in data science and engineering, and to explore the implications of using big data to learn about social interaction and organization. This Big Idea seeks to help us better understand, and more effectively develop, a cohesive, federated, national-scale approach to research data infrastructure, and knowledge needed to empower a 21st-century data-capable workforce. As part of **Harnessing the Data Revolution**, SBE's Resource Implementations for Data Intensive Research in the Social, Behavioral and Economic Sciences program seeks to develop user-friendly, large-scale next-generation data resources and analytic techniques to advance fundamental research in SBE areas of study.

SBE staff are also involved in all four of NSF's Enabling Ideas:

- Mid-Scale Research Infrastructure,
- Growing Convergence Research,
- NSF INCLUDES, and
- NSF 2026.

The Big Ideas are still getting underway and their many impacts are yet to be realized. A new award that shows an example of the types of insight that social, behavioral, and economic sciences can provide is titled, *Future of Work at the Human-Technology Frontier: Collaborative Research: The Next Mobile Office: Safe and Productive Work in Automated Vehicles.*[3] The goal of this project is to understand how current and future technologies might enable work to be done in automated vehicles. The project focuses on understanding how technology can allow commuters to safely combine or switch between work and driving tasks. A new multi-interface in-vehicle environment for the support of work-related tasks, as well as safe driving, in automated vehicles will be developed and tested in driving simulators and real vehicles.

[3] www.nsf.gov/news/news_summ.jsp?cntn_id=297116

BROADENING PARTICIPATION

Question 2. The NSF has a strong track record of providing research support to institutions with large research programs. However, many students of color, first generation college students, socioeconomically disadvantaged students, and other underrepresented groups in STEM attend emerging research institutions which are less likely to have substantial NSF research programs. What is the proportion of NSF research funding that is awarded to institutions that have high proportion of minority students? Similar to how the NSF EPSCoR program assists certain states with developing their research capacity, could NSF offer any such program for emerging research institutions in non-EPSCoR states?

Question: What is the proportion of NSF research funding that is awarded to institutions that have high proportion of minority students?

Answer: Each year, in accordance with The National Science Foundation Authorization Act of 2002 (P.L. 107-368, Section 18), NSF provides a report to Congress on its investments to support minority-serving institutions (MSIs). In FY 2018, NSF's total direct funding to MSIs was $771.9 million.

Question: Similar to how the NSF EPSCoR program assists certain states with developing their research capacity, could NSF offer any such program for emerging research institutions in non-EPSCoR states?

Answer: Since "emerging research institutions" (ERIs) is not a standardized term, NSF will follow the definition used by the National Academies in its report of a workshop entitled, "Partnerships for Emerging Research Institutions" (National Academy of Engineering and National Research Council, 2009[4]), i.e., master's colleges and universities, baccalaureate colleges, and tribal colleges and universities.

NSF currently provides multiple funding pathways for ERIs through research funding opportunities and targeted programs. Examples of NSF's targeted programs include: the Louis Stokes Alliances for Minority Participation program, the Facilitating Research at Primarily Undergraduate Institutions programs, Research in Undergraduate Institutions and Research Opportunity Awards; the Historically Black Colleges and Universities Excellence in Research; and Research Initiation Awards programs. Additionally, NSF's disciplinary activities include programs such as Broadening Participation in Computing and GEO Opportunities for Leadership in Diversity. This approach enables NSF to nurture emerging research institutions while maintaining the rigor of its merit review process.

Many of the barriers and solutions that the National Academies' Partnerships for Emerging Research Institutions workshop report describes are focused on actions within ERIs themselves. However, the report notes the importance of access to research infrastructure. An important way in which NSF addresses this need is through its Major Research Instrumentation (MRI) program. MRI provides the cutting-edge instrumentation that modern research groups require to conduct their research. MRI maintains similar funding rates for Ph.D.-granting and non-Ph.D. granting institutions of higher education (IHEs), waives the cost-sharing requirement for non-Ph.D. granting IHEs, and conducts outreach to emerging research institutions in various fora.

[4] www.nap.edu/catalog/12577/partnerships-for-emerging-research-institutions-report-of-a-workshop

It is unlikely that an analogue of the EPSCoR program would be feasible for ERIs. An important factor underlying the success of the EPSCoR program is the considerable infrastructure provided by the EPSCoR jurisdictions (typically a state or territory) themselves. Each jurisdiction develops and maintains a jurisdiction-wide strategic plan. Major EPSCoR proposals are typically submitted collaboratively by groups of institutions on research themes that are aligned with the jurisdiction's strategic plan. These collaborations are usually led by the research-intensive universities within each jurisdiction. The proposals are subject to rigorous merit review and only the most meritorious receive funding ensuring that the research is of high quality.

For emerging research institutions inside EPSCoR states, a key factor is the opportunity to leverage partnerships with more research-intensive organizations to submit collaborative proposals. Even without an EPSCoR-like program, ERIs outside EPSCoR jurisdictions have similar opportunities to partner with research-intensive institutions because most NSF research programs welcome collaborative proposals.

National Innovation Network

Question 3. Earlier this year, I introduced the Innovators to Entrepreneurs Act of 2019, which would expand the I-Corps program by allowing additional teams, including Small Business Innovation Research Program grantees, to participate. This bill was supported by a number of my colleagues, including Science Committee Chairwoman Johnson and Ranking Member Lucas, and passed the House floor at the end of February. If this bill is eventually signed into law, how could the additional partnership opportunities allow for even greater expansion of the NSF I-Corps program and growth of the National Innovation Network?

Answer: To build on the success of NSF's Innovation Corps (I-Corps™) program and fully realize its potential to help expand the Nation's innovation ecosystem, scaling up the I-Corps™ program is essential. Since its inception, I-Corps™ has had a strong connection to the Small Business Innovation Research (SBIR) and the Small Business Technology Transfer (STTR) programs. I-Corps™ collaborates with NSF's SBIR/STTR program to offer a condensed version of I-Corps™ called the "Beat-the-Odds Bootcamp" to Phase I grantees. This program was expanded in FY 2019 as a pilot to allow these grantees to apply for the full I-Corps™ Teams program and to receive supplemental funding to support their customer discovery work.

NSF also collaborates with the SBIR/STTR programs at the Department of Homeland Security (DHS) and the National Aeronautics and Space Administration (NASA) to allow their SBIR/STTR companies to apply for I-Corps™. The I-Corps program run by the National Institutes of Health (I-Corps@NIH) is focused on NIH SBIR/STTR Phase I companies. Beginning in late FY 2019, the NSF program will pilot a co-learning approach where academic teams potentially participate side-by-side with SBIR/STTR Phase I companies from NSF, DHS, and NASA.

New avenues to expand the pool of potential applicants to the I-Corps Teams program will, by extension, expand the reach of the National Innovation Network. NSF makes Phase I awards to roughly 300 small businesses each year, most of which are new startups, and 95 percent of which have not received prior SBIR/STTR Phase II funding from any government agency. Expanding eligibility for I-Corps to these awardees is seen as a way to improve commercial outcomes from NSF's SBIR/STTR program.

Questions for the Record Submitted by Steve Cohen

BROADENING PARTICIPATION IN STEM

Question 1. I'm deeply concerned about the proposed draconian cuts NSF is proposing for STEM programs. I am concerned that these cuts, if implemented, would significantly reduce the number of people that NSF would be able to engage. In particular, I'm troubled by the impact this would have on underrepresented minorities. The Administration's budget proposes to cut these programs by nearly $170 million, as compared to FY 18. How would these cuts impact NSF's efforts to broaden participation in STEM at the undergraduate and graduate levels? What impact would that have on NSF' s ability to increase the diversity of the science and engineering workforce?

Answer: NSF remains committed to advancing and leveraging its broadening participation portfolio. For FY 2020, NSF developed a Budget Request that funds discovery, learning, and the development of a diverse scientific workforce, investing strategically to maximize impact.

Broadening participation remains a priority investment area for NSF, and which is demonstrated by many research awards emphasizing it as part of their broader impacts. NSF will continue to leverage high-profile programs like NSF INCLUDES and Established Program to Support Competitive Research (EPSCoR) to provide national leadership, expansive partnerships and new directions for building an inclusive STEM (science, technology, engineering, and mathematics) workforce, involving stakeholders and contributors to STEM pathways at every level. Further interagency and industrial cooperation is anticipated in the shared responsibility of increasing diversity in the science and engineering workforce.

Unfunded Meritorious Proposals

Question 2. In your March 26th testimony before the House Commerce, Justice, Science and Related Agencies Appropriations Subcommittee, you mentioned that "about $4 billion in very good to excellent proposals are not funded by NSF due to the level of federal funding received by the agency." If Congress were to provide a significant increase in funding to NSF for FY 20, what areas of research or types of programs would that support?

Would the increase in funding be distributed proportionately across scientific disciplines?

Answer: NSF supports a broad range of fundamental research at the frontiers of discovery that probes difficult questions vital to our Nation's well-being. While one cannot always predict where the next big breakthrough will occur, NSF facilitates dialogue and fosters collaborations that enable our brightest minds to find answers. To identify and fund these bold ideas, NSF will continue to employ its gold standard merit review process that is emulated world-wide.

As described in NSF's Budget Request to Congress, in FY 2020 NSF will continue its commitment to core basic research across all disciplines and to the interdisciplinary efforts that underpin the Big Ideas. NSF expects to fund a combination of new strategic science proposals and core basic research to bolster funding rates and award sizes and duration. NSF funding supports important work in Advanced Manufacturing, Artificial Intelligence, Quantum Information Sciences, semiconductors/ microelectronics, and cybersecurity as well as research on the education and training required for a 21st century economy.

NSF INCLUDES

Question 3. The NSF INCLUDES program was established to catalyze the STEM enterprise to collaboratively work for inclusive change. The inaugural awards were made in 2016; Vanderbilt University, partnered with three other universities, received one of those awards. In the time since these awards were made, what specific outcomes or lessons learned have you identified?

Answer: Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (NSF INCLUDES) Design and Development Launch Pilot projects were funded in fiscal years 2016 and 2017 as two-year funding opportunities to explore the feasibility of bold, innovative ways of using partnerships and collaboration to solve a broadening participation challenge in STEM. Like most of the NSF INCLUDES launch pilot projects, Vanderbilt University and its partners (Auburn University, Alabama State University, and Tuskegee University) learned the positive effects of iterative implementation and (1) leveraging the science of broadening participation research and collaborative change strategies to build the evidence base for addressing broadening participation challenges; (2) using data to not only capture project outcomes, but also to refine goals and implementation strategies; and (3) accumulating knowledge through experimentation and implementation and diffusing knowledge gained across the launch pilots to build the NSF INCLUDES National Network. Specific outcomes of the *Southeast Alliance for Persons with Disabilities in STEM* launch pilot, awarded to Vanderbilt University and its partners, include expansion of the original Alabama Alliance, which provided academic and social support to over 200 students with disabilities in seven years, to 21 institutions in six southeastern states and the District of Columbia. More information on this launch pilot is available, which is working to improve the underrepresentation of individuals with disabilities in STEM programs and careers.[5]

An NSF INCLUDES developmental evaluation using a mixed-methods approach was conducted to provide real-time feedback to support strategic decision making and iterative development. Some outcomes reported from the first-year implementation of Launch Pilot projects include :

- Engaged over 20,000 participants and almost 1.3 times as many unique partner organizations than proposed. Partner organizations are involved in project leadership, intervention implementation, and design input.
- Involved more than half of the potential partner organizations identified in proposals (403 of 704) and added 487 new partner organizations.
- Reported conducting a range of activities that included a broadening participation (BP) intervention such as piloting an after-school program or developing a STEM course.
- Over 75 percent of Launch Pilots reported progress on BP, such as improving underrepresented students' attitudes towards STEM or improving launch pilot partners' understanding of underrepresented students' needs.
- Over ninety percent of Launch Pilots reported creating a variety of products that contribute to the knowledge base of BP in STEM. These include project websites, journals, presentations, conference papers, reports, publications, curricula, and intervention models.
- All Launch Pilots reported disseminating information about their project to multiple audiences, including other launch pilots, industry stakeholders, and community members.

[5] https://cws.auburn.edu/apspi/pm/includes

DIVERSITY AND INCLUSION IN STEM

Question 4. How is NSF planning to invest more in studying diversity and inclusion in STEM?

Answer: The Science of Broadening Participation (BP) program in the Directorate for Social, Behavioral and Economic Sciences (SBE) and the Broadening Participation Research track in the Directorate for Education and Human Resources' (EHR) programs will continue to invest in research to advance the knowledge base about diversity and inclusion in STEM. This research answers fundamental questions about what works to effectively expand the scientific talent pool. The EHR Core Research (ECR) program will continue to solicit proposals and support research on individual- and institutional-level factors that impact the learning and participation of groups underrepresented in STEM fields. Additionally, several other programs in EHR will continue to support large-scale research centers aimed at broadening participation. For example, the Louis Stokes Alliances for Minority Participation (LSAMP) Program is funding regional centers to conduct BP research and STEM implementation science activities to ensure that students who are underrepresented in STEM can advance the scientific and innovation skills of the Nation. The Historically Black Colleges and Universities Undergraduate Program (HBCU-UP) supports broadening participation research centers and serve as national hubs for the rigorous study and broad dissemination of the critical pedagogies and culturally sensitive interventions that contribute to the success of HBCUs in educating African American STEM undergraduates. The Tribal Enterprise Advancement (TEA) centers of the Tribal Colleges and Universities Program (TCUP) are investigating environmental, social, educational, and economic factors that promote the inclusion of tribal communities in addressing scientific challenges. The newly funded ADVANCE Resource and Coordination (ARC) Network and the NSF INCLUDES Coordination Hub support research networks aimed at identifying promising best practices.

Other mechanisms to study diversity and inclusion in STEM that are distributed across NSF's research directorates and offices include conferences and workshops for the development of BP-related research agendas in specific research domains. Additionally, NSF encourages secondary data analyses or deeper studies of the data reported in NSF's National Center for Science and Engineering Statistics' (NCSES) *Women, Minorities, and Persons with Disabilities in Science and Engineering report;*[6] and supports competitive research proposals focused on understanding gender equity, harassment, unconscious bias, and disability in the STEM context.

[6] https://ncses.nsf.gov/pubs/nsf19304/

Questions for the Record Submitted by Ranking Member Jim Baird

NSF MAJOR FACILITY CONSTRUCTION PROJECT STATUS

Question 1. There are currently three NSF construction projects in progress: The Daniel K. Inouye Solar Telescope in Hawaii, the Large Synoptic Survey Telescope in Chile, and three new research vessels. Are these projects all on schedule, and are there any difficulties with the projects that the Committee should be made aware of?

Answer: All three projects are on schedule and within current budget estimates, according to their closely monitored Earned Value Management metrics. They have had the normal set of issues that occur in major construction projects (e.g., bad weather on mountaintops, testing, and integration), and these have been dealt with using appropriate allocations of the schedule and budget contingency that were included in the total project costs and durations. Although GAO reports 18-370 and 19-227 suggested that the Daniel K. Inouye Solar Telescope (DKIST) had cost and schedule overruns, the project was re-baselined in 2013 because of realization of a risk out of the control of the project, namely a two-year delay due to administrative and legal challenges to the Conservation District Use Permit in Hawaii. NSF does not include cost and schedule impacts of uncontrollable events in the total project cost. Instead, the Director must request additional authorization from the National Science Board if the estimated project cost exceeds the level authorized by the Board at the time of award. Since that time, DKIST has remained within the revised cost and schedule, as approved by the National Science Board in August 2013, and is expected to be completed during FY 2020.

Questions for the Record Submitted by Anthony Gonzalez

NATIONAL ECOLOGICAL OBSERVATORY NETWORK (NEON)

Question 1. Could you please provide some insights into benefits and impacts you see for the NEON program, the importance of data collection at all sites with the same scientific protocols, and the value of having a 30-year life span for the program?

Answer: NEON is the first research observatory, and the only national facility, specifically designed to enable basic research on the Nation's ecosystems at regional to continental scales. NEON provides an unprecedented scale of identical and consistent measurements and observations to advance ecological understanding and to enable forecasting of ecological patterns and processes at the national scale. Just as weather forecasting for any one place requires measurements by standardized instruments and observations over the entire continent, the basic data needed to understand environmental processes must be acquired at regional to continental scales. Our ability to predict the consequences of climate variation, land-use change, emerging infectious diseases, and invasive species requires the capabilities of NEON.

Many processes in nature play out over decades or longer. NEON's design was optimized to provide long-term persistent, reconfigurable, and rapidly deployable infrastructure to respond to evolving understanding and abrupt and unpredictable events. The decision to operate the facility for 30 years was based on advice from numerous requirements assessments including the National Research Council and BIO's experience from the Long-Term Ecological Research (LTER) network. LTER research clearly demonstrated that understanding the ecological drivers and responses of environmental change requires multiple decades. In addition to understanding biological variability at regional to continental scales, the projected 30-year lifespan of NEON is intended to measure long directional changes.

Question 2. Could you please describe to us the various assets the NEON program offers to the ecological community, and the outreach plans to ensure researchers are aware of the opportunities to utilize the assets of the program to help empower their scientific efforts?

Answer: NEON offers multiple assets not only to the ecological research and education community but also other educators, data scientists, and citizens interested in questions about nature. Data from individual NEON sites is also used by the local land-management entities, including several Federal and state agencies, for their mission-driven research and planning. The data and data portal, facilitation of site access to conduct complementary research, the specimen repository, and training workshops are all available to researchers and the public at no cost. These resources are used in research and teaching, allowing all researchers, instructors, and students to work with cutting-edge environmental data at continental scale. Furthermore, the Assignable Assets program allows researchers to bring NEON instrumentation to their sites, or otherwise request that non-standard NEON resources be deployed at cost-recovery charge to the researchers. For example, the NEON airborne observation platform is a suite of sensors deployed on leased planes- highly sophisticated imaging instruments that can measure biological characteristics on the ground with fine spatial resolution and over broad areas. Five mobile deployment platforms that are ground-based allow researchers to place NEON's full suite of sensors anywhere that can be reached by wheeled vehicles. NEON field staff can be hired to conduct biological sampling that is not already included in standard sampling protocols performed by the project.

NEON engages the larger scientific community and citizens through scientific conferences as presenters and exhibitors. NEON scientists collaborate with investigators from universities, research institutes, and private companies. NEON conducts training workshops on college campuses, at scientific meetings, and at its headquarters in Boulder, Colorado to teach educators and scientists how to access and use the data. NEON publishes data tutorials, teaching modules, and science videos (search for "NEON" on YouTube—there is even a NEON Science channel), citizen science activities, and K-12 data activities. NEON frequently collaborates with the Ecological Society of America, the primary professional society for ecology (~10,000 members), on workshops, webinars and other initiatives that reach its membership. In addition, NSF highlights NEON resources in its requests for proposals and funds community-driven workshops focused on NEON science.

Questions for the Record Submitted by Troy Balderson

NSF INCLUDES

Question 1. During your testimony, you mentioned that NSF funds a number of grants that support research into the challenges facing rural communities in the recruitment and retention of STEM students. You specifically mentioned that the INCLUDES programs supports some of this work. Can you please provide a summary of the INCLUDES grants that focus on broadening participation in rural communities? In addition, please highlight any other research NSF is supporting to examine and address this challenge.

Answer: NSF has an extensive broadening participation portfolio that impacts rural communities. Eight NSF INCLUDES awards include a focus on rural students. The First2 STEM Success Network is an alliance of students, educators, and policy makers in West Virginia that is building on the success of a funded launch pilot to improve college enrollment and success for undergraduate STEM students, particularly those who are rural, first-generation students, in their first two years of college. Six other design and development launch pilots that focus on indigenous students and students in the Pacific Northwest, northern New Mexico, Georgia, and South Carolina also engage rural students in their work.

Education and Human Resource (EHR) programs, in general, support the recruitment and retention of undergraduate and graduate students historically underrepresented in STEM in rural communities. EHR programs provide support to the universities and colleges that serve rural communities and to investigators conducting STEM disciplinary or education research in rural areas. EHR programs that provide support of rural programs include Tribal Colleges and Universities (TCUP), Historically Black Colleges and Universities (HBCU-UP), Hispanic Serving Institutions (HSI), Louis Stokes Alliances for Minority Participation (LSAMP), Alliances for Graduate Education and the Professoriate (AGEP), NSF INCLUDES, and Centers for Research Excellence in Science and Technology (CREST) programs. In addition, Excellence Awards in Science and Engineering (EASE) presidential award program recognizes outstanding STEM mentoring and STEM K-12 teaching across the country and many awardees come from rural areas. Both Innovative Technology Experiences for Students and Teachers (ITEST) and Advancing Informal STEM Learning (AISL), broadening participation programs, have additional review criteria that evaluate proposals in terms of how they identify underserved groups, identify their strengths and needs and why the project is designed to build on those strengths and serve those needs within all communities. In addition, Discovery Research PreK-12 (DRK-12) has a special emphasis on proposals for research on resources, models, or tools that are designed to encourage and support girls and students with disabilities. The NSF Scholarships in STEM program (S-STEM) supports academically talented students with demonstrated financial need from institutions across the U.S., including those in rural areas. Additionally, S-STEM projects employ curricular innovations and proven non-curricular approaches such as faculty mentors, student cohorts, living-learning communities, and other student support activities to increase retention and graduation. Through these efforts S-STEM projects also build knowledge about factors that promote student persistence and degree attainment in STEM. Foundational research on STEM education in rural settings is also supported by the EHR Core Research (ECR) program.

In addition to EHR programs focusing broadly on broadening participation in rural communities, the other research directorates fund broadening participation within rural communities typically within their specific scientific discipline.

Responses by Dr. Diane Souvaine

HOUSE COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY
SUBCOMMITTEE ON RESEARCH AND TECHNOLOGY

"A Review of the National Science Foundation FY 2020 Budget Request"

Questions for the Record to:
Dr. Diane Souvaine
Chair, National Science Board
National Science Foundation

May 8, 2019

Questions from Chairwoman Haley Stevens

1. **There are evolving demands for data from the National Center for Science and Engineering Statistics (NCSES), including interest in collecting data on STEM workers without advanced degrees and the nature and prevalence of sexual harassment in STEM studies and careers. The FY 2020 budget request includes a nearly $5 million, or 9 percent, cut to NCSES.**
    - **Can you talk about the current workload of NCSES and its capacity to expand the scope of that work to address emerging policy interests?**
    - **What budget would be needed to allow NCSES to take on these new activities?**

While we defer to the Director on the specifics of budget and staffing levels within any unit of the National Science Foundation and are cognizant that NCSES - as an independent Federal statistical agency - has a distinct mandate to fulfill, the National Science Board (NSB, Board) remains vigilant and concerned about NCSES' workload. In addition to making its data more useful and timely for our stakeholders, a primary goal of our "reimagining" of the Board's flagship Congressionally-mandated report, *Science and Engineering Indicators*, is to ensure that the production of this rich and substantive report is sustainable for our NCSES partners. We hope that the new model for *Indicators*, which beginning with the 2020 edition will be published as a series of streamlined, focused reports rather than as one massive volume, will allow NCSES to better balance workload demands throughout the two-year *Indicators* "cycle" and better leverage the work performed across the suite of NCSES reports as input to *Indicators*.

The Board supports efforts to have NCSES collect data on emerging policy topics of critical interest and importance to the nation's science and engineering (S&E) enterprise, such as the Skilled Technical Workforce and the prevalence of sexual harassment in STEM. The Board notes that having NCSES located within NSF greatly aids the Agency's ability to be responsive to such emerging questions. The Board expects that some efficiencies can be gained by the reimagining of *Indicators* and other efforts within NCSES. However, NSB believes realizing NCSES' potential contributions to such topics would require new resources, including both personnel and money.

2. **With the completion this year of the Daniel K. Inouye Solar Telescope, and construction of the Large Synoptic Survey Telescope slated for completion in FY 2022 and the Antarctic**

Infrastructure Modernization for Science Project in FY 2023, it appears there will be a gap in major facilities construction at NSF by FY 2024. We looked back well over a decade and NSF has not had a gap in major facilities construction projects. What is on the horizon for major research facilities construction at NSF? What is the status of NSF' s planning for these facilities?

While the five-year projection for MREFC projects currently shows a pending gap, and that warrants attention, that projection has also occurred in the recent past (see, e.g. NSB's FY 2014 Annual Portfolio Review of Facilities). NSF engages in a continual cycle of project development, design, and analysis to further the quest for science through world-class research infrastructure; the Foundation is certainly exploring ideas for large facilities.

As part of that process, the National Science Board takes seriously its responsibility to work with NSF to ensure the health and sustainability of its research infrastructure portfolio. As the cost of constructing and operating this infrastructure increases, the Board is mindful of the need for strong research community commitment to these investments, thoughtful agency-level planning, pursuit of interagency and international partnerships to help share costs (when appropriate), and a balance between NSF's infrastructure and research investments. The Board's 2018 infrastructure-related reports to Congress, "Study of Operations and Maintenance Costs for NSF Facilities" and "Bridging the Gap: Building a Sustained Approach to Mid-scale Research Infrastructure and Cyberinfrastructure at NSF" address agency-level planning and strategic balance at both the mid-scale and major research facility levels. As the strategic analysis on future infrastructure investments proceeds, the cost of construction, combined with the longer-term commitments to operations and maintenance, should be evaluated to ensure a sustained investment in core research.

In its approval of NSF's FY 2020 Budget Request, NSB unanimously endorsed using the Major Research Equipment and Facilities Construction account to support Mid-Scale Research Infrastructure (MSRI)-2 awards. The Board's 2018 Midscale Report encouraged NSF to develop a sustainable agency-level midscale research infrastructure program; both NSB and NSF anticipate that the MSRI-2 program will continue as part of the MREFC portfolio through FY 2024 and beyond. It is likely that some mid-scale research infrastructure projects will pave the way (both scientifically and as engineering demonstrations) for future major facility projects. At its July 2018 meeting, NSB approved the inclusion of the High Luminosity upgrades for the Large Hadron Collider's ATLAS and CMS detectors in future budget requests. This project is in NSF's FY 2020 Budget Request and, if approved, would have a budget profile continuing through FY 2024.

The Board's Committee on Awards and Facilities is constantly monitoring NSF's portfolio of infrastructure investments. The Committee and the full Board are committed to balancing science community input with agency-level planning in making decision about future large facilities. For that reason, as we look towards future major facilities projects, NSB watches with great interest the outcomes of decadal surveys and other disciplinary community planning processes. In late 2020 or early 2021, the National Academies of Science, Engineering, and Medicine will release its 2020 decadal survey in astronomy and astrophysics. If history is any predictor, the Board expects to see

recommendations for new, more capable telescopes. Similar recommendation and prioritization processes are also underway in other fields including Earth Sciences.

Given these processes and the demand associated with NSF's recent MSRI solicitations, the Board remains confident that NSF's future budget requests for the MREFC line will continue to be robust. Potential projects currently in development or the early design stages will appear in budget requests once approved by the Board for inclusion in a future budget. This Board action occurs roughly 2/3 of the way through the design process. As such, recommendations from the 2020 astronomy and astrophysics decadal survey, for example, could likely find themselves in the budget requests of the mid-2020s. Depending on the outcomes of the various community processes, there may be a case in the future for considering an increase to MREFC account line. Any decisions need to be made in the context of NSF's entire Budget so that new projects do not jeopardize the funding for research programs.

Questions from Congressman Dan Lipinski

1. **The NSF has a strong track record of providing research support to institutions with large research programs. However, many students of color, first generation college students, socioeconomically disadvantaged students, and other underrepresented groups in STEM attend emerging research institutions which are less likely to have substantial NSF research programs. What is the proportion of NSF research funding that is awarded to institutions that have high proportion of minority students? Similar to how the NSF EPSCoR program assists certain states with developing their research capacity, could NSF offer any such program for emerging research institutions in non-EPSCoR states?**

The Board is pleased to note that the funding patterns reported in the Merit Review Report show that NSF is successfully funding emerging research institutions. The proposal funding rates for four-year, baccalaureate institutions were 23%, which is quite similar to the 25% funding rate for the top 100 Ph.D.-granting institutions. The funding rates for two-year institutions and minority-serving institutions were also similar, 28% and 21% respectively.

The most recent NSF Merit Review Report (https://www.nsf.gov/nsb/publications/2018/nsb201915.pdf), which was published shortly after the Subcommittee hearing, notes that "program officers strive to fund proposals from diverse institution types across all 50 states, from both new and experienced investigators." This includes higher education institutions that are considered "emerging research institutions," which the National Academics defines as masters' colleges and universities, baccalaureate colleges, and tribal colleges. While in principle NSF could implement a capacity building program for emerging research institutions, given funding constraints, the Board believes that NSF appropriately balances programs to promote the progress of science.

For its funding decisions, the Foundation considers both the Intellectual Merit and Broader Impacts of the work proposed. Pertinent to institutions that are aspiring to build research programs, the Broader Impacts review criteria allows proposers to highlight opportunities to improve research capacity as a valuable aspect of their projects and enables program officers to consider such capacity building as a relevant objective when making funding decisions. The Broader Impacts criterion is valuable in the eyes

of the National Science Board. It allows the Foundation to support a large variety of scientific and social benefits, including fostering the emergence of research institutions in all states, and it can accommodate many important needs and opportunities identified the by the scientific community in emerging research institutions regardless of the state in which they are located.

The Board also notes that NSF conducts in-person engagement sessions across the nation that are designed to help institutions and researchers learn how to improve their NSF funding success rates. In 2018, these "NSF days" were located in spots that were convenient to many baccalaureate, masters-granting, and tribal universities and colleges: University of New Mexico, South Dakota State University, Tennessee State University, and University of Alabama at Birmingham.

Questions from Congressman Steve Cohen

1. **The NSF INCLUDES program was established to catalyze the STEM enterprise to collaboratively work for inclusive change. The inaugural awards were made in 2016; Vanderbilt University, partnered with three other universities, received one of those awards. In the time since these awards were made, what specific outcomes or lessons learned have you identified?**

NSF plays a critical role in helping educate and train the next generation of STEM-capable workers. For the United States to remain competitive, we must ensure that people of all backgrounds have the opportunity to participate in STEM and build valuable, fulfilling careers. NSF's Inclusion across the Nation of Communities of Learners of Underrepresented Discoverers in Engineering and Science (INCLUDES) program is a comprehensive initiative to enhance U.S. leadership in science and engineering discovery and innovation by proactively seeking and effectively development STEM talent from all sectors and groups in our society. Begun in 2016, NSF INCLUDES aims to build on and scale-up broadening participation work and research via the creation of a national network of alliances and partnerships. Collaborative change networks are the core mechanisms that NSF INCLUDES employs to address broadening participation challenges and solve complex problems that otherwise could not be tackled by a single institution or investigator. A key feature of NSF INCLUDES is its focus on uniting a wide variety of collaborators to generate pioneering solutions to persistent problems.

In 2017, NSF INCLUDES issued 27 new Design and Development Launch Pilot Awards aimed at developing blueprints for collaborative change among a set of public-private partners to address broadening participation challenges. These pilot programs will create an infrastructure that enables large-scale coordination, fueling future innovations in broadening participation in STEM participation. In 2018, NSF released a solicitation for the NSF INCLUDES Alliance proposals. The goals of the INCLUDES Alliances are to develop a vision and strategy for broadening participation in STEM, along with relevant metrics of success and key milestones to be achieved during the project's lifecycle, contributing to the knowledge base of broadening participation in STEM; develop multi-stakeholder partnerships and build infrastructure; and advance a logic model or other heuristic that identifies alliance outcomes that reflect implementation of change at scale and progress toward developing an inclusive STEM enterprise. While the Board defers to NSF on specific "lessons learned" to date, we note that the elements of the INCLUDES initiative (Pilot Awards, Alliance proposals) are still in their initial stages,

so it is not yet possible to do a systematic evaluation of outcomes for this new program. Initial observations, however, do support the theory behind the idea. According to a briefing presented to the Board in July 2018, NSF INCLUDES' 70 launch pilots have attracted over 750 partners in 45 state and U.S. territories from across the spectrum of targeted communities; academia, business, scientific, and diversity promotion. Initial reporting indicates that collaborative infrastructure is being built with partners from diverse geographic and experiential backgrounds representing industry, laboratories, community organizations, non-profits, government agencies, schools, community colleges, and universities. There is more evaluation to be completed as the program matures to fully assess scalability and sustainability, but the early results are promising.

Questions from Ranking Member Jim Baird

1. **How is the National Science Board conducting its oversight role of the three current NSF construction project: The Daniel K. Inouye Solar Telescope in Hawaii, the Large Synoptic Survey Telescope in Chile, and three new research vessels?**

The NSB provides oversight of facility construction projects though its annual budget process, award actions and policies, through the Committee on Awards and Facilities' ongoing monitoring of the research infrastructure portfolio, and through the Committee on Oversight's monitoring of audits and Office of the Inspector General activities. From a budgetary standpoint, the NSB approves annually the Budget Submission to OMB and receives periodic updates from NSF on the current plan. Both mechanisms allow NSB to track progress on facility construction while also monitoring the MREFC line. By statute, the Board approves construction awards for all projects funded with MREFC funds, and the Board's Delegation of Authority requires that awards that see the lesser of a $10 million dollar increase or an increase of 20% of total cost must return to NSB for further Board action.

The Committee on Awards and Facilities also has a variety of mechanisms for conducting oversight. The Committee conducts an annual comprehensive examination of the NSF portfolio of infrastructure investments including possible future projects, progress on projects in construction, and the transition of facilities from construction to operations. In addition, the Committee's Chair and Vice Chair receive bi-monthly reports on the progress of facilities in construction. NSF's Chief Officer for Research Facilities provides the Committee with an Annual Report that among other items includes information on facilities in construction. NSF divisions also provide the Board with updates when identified project risks are realized. Additionally, small groups of NSB members periodically participate in site visits; in 2016, several NSB members visited DKIST, and this fall several will visit the LSST site.

2. **In your testimony you mentioned that the United States, with respect to basic research, is in danger of "eating its own seed corn." Can you please elaborate on what you meant by that statement?**

When we worry that the nation is "eating its seed corn" with respect to basic research, we mean that we are concerned that the nation is in danger of failing to make an appropriate level of investments to

support two things: (1) the kind of research that can yield fundamental breakthroughs in knowledge; and (2) the scientific personnel and facilities that can make such breakthroughs.

First, basic or fundamental research yields the kinds of foundational new knowledge that significantly improves our understanding of forces in the world, allowing us to see new ways to do or create or control things. Breakthroughs at fundamental levels are the "seed corn" for both economy-driving innovations and future fundamental advances. Without fundamental breakthrough, advances are mainly incremental. With them, major improvements are possible.

Fundamental research tends to be highly uncertain. It is hard to know in advance which approaches will pay off and many projects do not succeed. This makes basic research unattractive to private industry. But the U.S. government has supported it historically, with the expectation that U.S. industry would build on the successful discoveries. Our U.S. innovation ecosystem has borne out that expectation, so that our basic research successes have more than justified the nation's investment.

For example, Charles Townes succeeded in creating intense beams of sub-millimeter radiation while working at Columbia. He called his beam the "maser" and he was eventually awarded a Nobel prize for his breakthrough. Within three years of the publication of Townes' results, an industry-based lab built on his basic findings to produce a laser, which led, through subsequent applied research and development, to lasers for spectroscopy; photochemistry; directed-energy weapons systems; new types of surgery, dentistry, and cancer treatments; optical fiber communications; consumer electronics advancements; and even the bar-code readers we use at the grocery store and that have made supply-chain management so much more efficient overall.

Many scientists at the time of Townes' work had reason to believe his approach to focused radiation was doomed to fail. His colleagues at Columbia -- including two Nobel laureates from his field – even tried to get him to stop his project, as they thought he was wasting resources that could be used for more promising research projects. Again: it can be hard to know which approach to fundamental science will ultimately lead to the breakthrough. But those that succeed often have far-reaching practical ramifications.

Many fundamental breakthroughs share similar stories:

- The basic research into DNA sequencing that led to the biotech industries, many new pharmaceuticals, personalized medicine, and even DNA uses in criminology.
- The basic research into rhythmic magnetic pulses that led to magnetic scanning and functional imaging for medical purposes.

The second type of "seed corn" associated with basic research is the scientific personnel engaged in leading edge work; the talented experts who are poised to either make the next breakthrough or quickly build on the breakthroughs of others. Basic research fields are hard, and it takes time to develop experts who understand them fully enough to conduct leading-edge inquiry. If we do not invest in a new field early, if we do not encourage and enable scientists to dedicate themselves to it even before it is clear where it will lead, we cannot easily jump into it later if it becomes promising. Relatedly, if we are investing in a field and stop, the relevant scientists will have to find other work, or they will have to find others to fund their work. The U.S. will be hard pressed to re-enter an important field if we have lost our

base of expertise. Thus, if we fail to provide robust and sustained funding in fundamental research, our deep cadre of world-class scientists and the potential fruits of their research are endangered.

Finally, the United States has long been committed to the idea that fundamental science – the kind of science that only the Federal government can and will fund – is the engine for exceptional innovation that leads to economic prosperity. This commitment led to significant investment that yielded breakthroughs that have fueled our spectacular economic success. Other nations have noticed our success and are furiously, explicitly imitating our model. Meanwhile, the U.S. government commitment to research and development as measured as percent of GDP peaked in the space race, producing a generation of scientists and engineers who came of age amid a clarion call to serve their country through research and technology. This is what raises the question: are we eating our seed corn and at what peril?

Appendix II

Additional Material for the Record

ADDITIONAL RESPONSE SUBMITTED BY DR. FRANCE CÓRDOVA

Testimony Insert #1 Page 65a, Line 1475
Committee on Science, Space, and Technology
Subcommittee on Research and Technology
May 8, 2019
Hearing on Appropriations for FY 2020 – National Science Foundation

NSF Programs in Rural Communities

NSF has an extensive broadening participation portfolio that impacts rural communities. Eight NSF INCLUDES awards include a focus on rural students. The First2 STEM Success Network is an alliance of students, educators, and policy makers in West Virginia that is building on the success of a funded launch pilot to improve college enrollment and success for undergraduate STEM students, particularly those who are rural, first-generation students, in their first two years of college. Six other design and development launch pilots that focus on indigenous students and students in the Pacific Northwest, northern New Mexico, Georgia, and South Carolina also engage rural students in their work.

Education and Human Resource (EHR) programs, in general, support the recruitment and retention of undergraduate and graduate students historically underrepresented in STEM in rural communities through support to the universities and colleges that serve rural communities and to investigators conducting STEM disciplinary or education research in rural areas through Tribal Colleges and Universities (TCUP), Historically Black Colleges and Universities (HBCU-UP), Hispanic Serving Institutions (HSI), Louis Stokes Alliances for Minority Participation (LSAMP), Alliances for Graduate Education and the Professoriate (AGEP), NSF INCLUDES and Centers for Research Excellence in Science and Technology (CREST) programs. In addition, Excellence Awards in Science and Engineering (EASE) presidential award program recognizes outstanding STEM mentoring and STEM K-12 teaching across the country and many awardees come from rural areas. Both Innovative Technology Experiences for Students and Teachers (ITEST) and Advancing Informal STEM Learning (AISL), broadening participation programs, have additional review criteria that evaluate proposals in terms of how they identify underserved groups, identify their strengths and needs and why the project is designed to build on those strengths and serve those needs within all communities. In addition, Discovery Research PreK-12 (DRK-12) has a special emphasis on proposals for research on resources, models or tools that are designed to encourage and support girls and students with disabilities. The NSF Scholarships in STEM program (S-STEM) supports academically talented students with demonstrated financial need from institutions across the U.S., including those in rural areas. Additionally, S-STEM projects employ curricular innovations and proven non-curricular approaches such as faculty mentors, student cohorts, living-learning communities, and other student support activities to increase retention and graduation. Through these efforts S-STEM projects also build knowledge about factors that promote student persistence and degree attainment in STEM. Foundational research on STEM education in rural settings is also supported by the EHR Core Research (ECR) program.

In addition to EHR programs focusing broadly on broadening participation in rural communities, the other research directorates fund broadening participation within rural communities typically within their specific scientific discipline.