Testimony of
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Subcommittee on Research & Technology
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"National Science Foundation: Advancing Research for the Future of U.S. Innovation"

Introduction

Chairwoman Stevens, Ranking Member Waltz and members of the subcommittee, it is my pleasure to appear before you today as the Chair of the National Science Board (NSB) to describe the Board's current work and priorities, and in particular, how the *National Science Foundation for the Future Act* and the Administration's fiscal year 2022 budget proposal address those priorities.

Fueled by the National Science Foundation (NSF) Act of 1950, U.S. leadership in science and engineering (S&E) has shaped Americans' way of life for seven decades, contributing to the nation's economic prosperity and ensuring its national security. When my predecessor, Dr. Diane Souvaine, testified before you in January 2020, she said, *"The past has shown that investment in basic research now will give us the keys to meeting the security, health, and economic challenges of the future – **challenges we know will arise but whose nature we cannot predict.**"* How prescient those words proved to be. It is thanks in no small part to that federal investment in basic research that we are at last beginning to emerge from an unexpected and devastating pandemic.

Perhaps now more than at any time in recent memory, Americans see the fruits of decades of basic and applied research as novel technologies, deployed at scale, have been developed by researchers and innovators to combat COVID-19 in record time. Yet the Board was so concerned about emerging S&E trends that we developed a vision for the future on what is needed to fuel an innovation economy and remain preeminent in science and engineering. We published *Vision 2030* close to a year ago; in developing it, the NSB spent a year examining data, revisiting internal and external reports, and consulting with S&E community members across the country. We gained insights from students, early-career and seasoned professors and researchers, and administrators from a variety of institutions; inventors and representatives of academic and scientific associations; NSF staff; and others. We undertook our work on *Vision 2030* with full consideration of NSB's dual

role as NSF's policymaking board and as an independent S&E policy advisor to both Congress and the President.

Vision 2030 is a guide to where the U.S. S&E enterprise **must** be in 10 years. It identifies trends and four key areas for U.S. leadership: Practice of Science and Engineering, Talent, Partnerships, and Infrastructure. Most importantly, it includes a roadmap for how the U.S. can reinvent aspects of its S&E enterprise to remain preeminent, including specific actions the NSB commits to taking over the next decade to contribute to this reinvention. *Vision 2030* offers ways to build on NSF's strengths and success, while enhancing the agency's ability to respond to new priorities and challenges. The time is right to invest in science, technology, and talent at the scale of our nation's S&E challenges, and NSF is the right agency for this job.

The Case for Urgency

In *Vision 2030*, the Board drew on data from our biennial *Science and Engineering Indicators* report to highlight three trends that must be considered in deciding how to build for the future.

Globalization of S&E

Since 2000, global research and development (R&D) investments have tripled. While the U.S. remains a leading player, other countries have seen the benefits of investing in research and education and are following our example. Adjusted for inflation, growth in U.S. total R&D averaged 3.3% annually between 2010-18. Yet while the U.S. S&E enterprise is growing in absolute terms, the global S&E enterprise is growing faster, so the U.S. share of discovery is dropping.

On the global stage, emerging economies, particularly in the Asia-Pacific region, are succeeding in their concerted efforts to become major S&E actors. China stands out for its rapid growth in the numbers of S&E degrees awarded, peer-reviewed S&E articles published, patents awarded, and its R&D spending. It is worth noting that most of the rise of China's R&D expenditures have been in experimental development, which is directed to produce new products or processes or improve existing ones. For now, the U.S. retains a significant lead in fundamental research, which is directed to acquire new knowledge and is the seed corn for America's entire S&E enterprise.

Growth of Knowledge- and Technology-Intensive Industries

Global growth in R&D investments reflects increased activity and competition in knowledge- and technology-intensive industries, such as pharmaceuticals and computer, electronic, and optical products. In the U.S., such industries account for 17% of GDP and generate $2.7 trillion in output, outpacing any other sector. Although U.S. output increased, the U.S. global share decreased slightly. China now produces about a quarter of the global output.

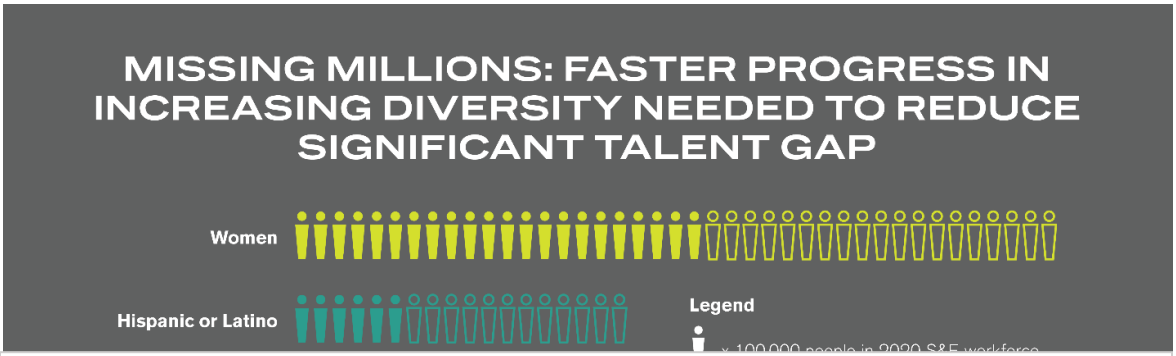
Since the turn of the century, the business sector has driven U.S. R&D spending growth, accounting for about 80% of the increase each year. However, the bulk of business R&D is applied research and experimental development, not basic research. Today's R&D intensive industries exist, in part, because of discoveries from *basic* research that the federal government funded decades ago, long before the research had a known application. Yet between 2000 and 2018 the share of basic research that is federally funded declined from 58% to 41%. This decline in the Federal government's share

of R&D funding is concerning because it is a critical source of support for the nation's basic and applied research enterprise across *all* S&E fields. Business basic and applied research is concentrated in a few areas, with much of their investment occurring in pharmaceuticals, transportation, and computing. Only the federal government can make a strategic, long-term commitment to creating new knowledge across all fields of science and engineering – including areas that cannot be anticipated to lead to new or improved technologies, goods, or services – and support risks that are difficult for the private sector to undertake.

Demand for STEM Talent

Through *Science and Engineering Indicators*, *Vision 2030,* and our policy reports, the NSB has persistently worked to raise awareness of trends in educational performance and demographics of the S&E workforce. Demand for workers with science, technology, engineering, and mathematics (STEM) skills keeps growing, driven by rapid increases in the number of jobs that require STEM skills, including in lines of work that historically did not require such knowledge. This situation will only become more urgent: by 2029, employment in STEM occupations is predicted to grow by 8% compared with 3.7% growth in overall U.S. employment.

Even as STEM competencies become more essential, the U.S. is falling behind in developing the full potential of its people. Despite recent emphasis on K-12 STEM education, U.S. science and mathematics education at the elementary and secondary level is mediocre relative to other nations, and over the last decade U.S. student performance has stagnated. In higher education, some progress has been made in diversifying the racial and ethnic composition of S&E degree recipients, reflecting population changes and growing rates of underrepresented groups who attain post-secondary degrees; however, the attainment gap across racial and ethnic minorities remains significant. There is a similar story for the S&E workforce. Despite some progress, women and racial and ethnic minorities remain underrepresented in the S&E workforce relative to their proportions in the U.S. population – and will remain underrepresented for years to come unless there are vast improvements in attracting and retaining these individuals in S&E education and jobs (see Figure).



While the number of people from underrepresented groups in the S&E workforce has grown over the past decade, much faster increases will be needed for the S&E workforce to be representative of the U.S. population in 2030. To achieve that goal, the NSB estimates that the number of women must nearly double, and Black or African Americans must more than double. Hispanic or Latinos, American Indians and Alaskan Natives, and Native Hawaiians or Pacific Islanders must triple their numbers. These estimates are based on projections from the U.S. Census and Bureau of Labor Statistics, together with data from the National Center for Science and Engineering Statistics and assume that participation of these groups in the S&E workforce increases at current rates.

These three trends lead to three key questions:

- How can America keep its lead in fundamental research?
- How can American discoveries continue to empower U.S. businesses and entrepreneurs to success globally?
- How can the U.S. increase STEM skills and opportunities for all Americans?

In addressing these questions, the NSB highlighted four elements that are essential to the U.S. remaining the world leader in innovation.

Key Elements of Leadership

Practice of Science

In a highly competitive global S&E environment, the U.S. must stay on the leading edge of the practice of S&E, improving the research environment and setting the standard for research ethics and values. With greater international competition comes the need to speed the movement of research from the laboratory to product. The U.S. must also invest more strategically across all fields and across the nation, embrace new research tools and modalities, foster an inclusive S&E enterprise, and welcome – as well as capitalize on – the globalization of S&E.

Talent

To remain competitive, the U.S. must be a STEM talent powerhouse. To be ready for 2030, the U.S. will need a research and development workforce, from skilled technical workers to PhDs, that pushes the frontiers of knowledge, within a strong STEM-capable workforce in which many more Americans have the skills to thrive in a knowledge and technology-intensive economy. To meet these needs, the U.S. must take a two-pronged approach: expand domestic talent and attract global talent, while working to retain both groups in STEM.

Infrastructure

The world's best talent – including American talent – will go where the S&E opportunities are greatest. Data, software, computation, and networking capabilities, as well as the facilities needed to conduct science, help make the U.S. competitive in S&E. To sustain global leadership, the U.S. needs to continue to invest in research infrastructure, creating opportunities for researchers in all parts of the country and at a range of institutions.

Partnerships

The U.S. must strengthen existing partnerships particularly in the face of competition from countries that organize their S&E enterprises much more centrally. To make the most of investments in fundamental research, the U.S. should strengthen interagency coordination and add more partnerships with the private sector, state governments, and philanthropic organizations. In addition, fostering international partnerships with like-minded partners will encourage collaboration in S&E research that involves unique and costly research infrastructure.

NSB Roadmap

The Nation's entire S&E ecosystem must be involved to ensure that the U.S. has a thriving S&E enterprise in 2030. For its part, the NSB developed a broad roadmap emphasizing four key areas of efforts to which it committed, in partnership with NSF and other leaders in the S&E enterprise:

- deliver benefits from research,
- develop STEM talent for America,
- expand the geography of innovation, and
- foster a global S&E enterprise.

The strong complementarity between these areas and NSF's three core pillars (advancing the frontiers of research into the future; ensuring accessibility and inclusivity; securing global leadership in science and technology) that Dr. Panchanathan and his leadership team have developed, underscores the partnership between and mutual goals of the NSB and NSF. Here I will focus on the first two roadmap areas, as the Board has done over the past year.

Deliver Benefits from Research

An ethos of service to the nation through science is a thread that runs from Vannevar Bush's 1945 *Science – the Endless Frontier,* through the original NSF Act, NSB's *Vision 2030,* and this committee's NSF reauthorization bill. This area of the roadmap focuses on significantly expanding and enhancing the return to U.S. taxpayers from S&E investments, both to contend with pressing challenges and to empower the nation's businesses and entrepreneurs to compete globally. As Dr. Panchanathan notes, both exploration and translation are intertwined and part of the DNA of NSF.

In *Vision 2030*, NSB reiterated its endorsement of the principle that all NSF-funded research and education must further the national interest by contributing to NSF's mission. While several agencies invest in fundamental research, NSF is the only agency whose mission is to do so across a wide breadth of disciplines. Its practice of supporting curiosity-driven research has provided the basis for technologies and benefits that could not have been anticipated at the time of initial funding. Yet the research community has far more ideas and capacity than NSF can fund. In 2019, for example, NSF was unable to fund research proposals totaling nearly $3 billion that were rated "Very Good" or higher. The grants that NSF does award are often shorter in duration and smaller in size than optimal, forcing researchers to spend time on proposal writing rather than on research and student mentoring. NSB is heartened that the draft bill's authorization levels will allow more of those seeds of basic research to germinate, and that the Administration's topline budget request for NSF also provides an increased level of investment.

In the last 15 years Congress and NSF have taken important steps to ensure that the U.S. and its taxpayers benefit from the research it supports, creating new programs to enhance translation and instituting policies on research in the national interest, accountability and transparency, and enhancing the broader impacts review criterion. NSB committed in *Vision 2030* to evaluate how NSF's Broader Impacts merit review criterion can better meet societal needs. We welcome the bill's request for an assessment of how NSF applies the Broader Impacts review criterion across the agency, which would build on work already being done by NSF's Office of Integrative Activities and the Board's Committee on Oversight. The Board has held listening sessions and met with experts and stakeholders within and external to NSF. In February 2021, the Board passed a

resolution designed to improve the current merit review process by including Broader Impacts expertise on external panels that inform NSF and NSB evaluations of programs and processes.

In *Vision 2030*, NSB highlighted the need for NSF to develop structures, processes, and partnerships that accelerate translation of discoveries, including for convergent research inspired by societal problems. The NSB is excited about the opportunity to make changes that will help realize the Vision. While the Board did not define specific changes, we identified key principles and priorities for any changes and new structures. Freedom to follow S&E opportunities has made NSF successful for 70 years and continued programmatic agility will be crucial as NSF evolves to meet the next 70 years. Use-inspired research should be an agency-wide priority that is reflected in NSF's strategy and not siloed in one area. Any new directorate should work synergistically with the existing directorates, strengthen NSF's basic research mission, and create robust feedback loops to integrate the work of the new directorate with the current discipline-oriented directorates. The desired outcome will depend on breaking down silos, not creating new ones. A structure that is clear and consistent with existing practices – including ensuring that the Board has the same governance role for the new directorate that it plays for all other directorates – will help ensure its cross-cutting nature. Funding for any new directorate will need to include support for personnel, for both the ramp up and operational phases. And these efforts should include a focus on talent development, especially diverse, domestic talent, about which more will be said in the next section.

In that vein, the Board appreciates that the *NSF for the Future Act* includes provisions that would help connect the curiosity-driven and use-inspired research that NSF supports throughout the agency, creating greater opportunities to use that knowledge to address societal problems. It includes the Board's desired flexibility for the agency to experiment with new models, funding mechanisms, and ways to encourage more nimble and rapid processes agency-wide. And, as the Board has recommended, the proposed governance plan and structure is clear and readily implementable with the Board maintaining its overall governance and oversight role.

Progress in delivering benefits will also require that players across the U.S. S&E ecosystem collaborate, cooperate, and partner more frequently and more effectively. The Board notes that the NSF for the Future Act also encourages an ecosystem of partnerships and collaborations, including engagement of nontraditional players. Director Panchanathan is laying the groundwork by meeting with leaders across the federal government, industry, academia, scientific societies, foundations and more to discuss areas of mutual interest and benefit. He also has an internal team working on reducing structural and administrative barriers to partnerships, which recently unveiled a partnerships portal for NSF employees to facilitate agreements. In addition, the Board looks forward to working with the Director, the Administration, and Congress to facilitate the exchange of people, and with that the exchange of ideas and expertise, among federal agencies, universities, and industry, including through programs like the Industry – University Cooperative Research Centers and Convergence Accelerators.

In its FY 2022 budget, the Administration has also proposed a new directorate for NSF, focused on Technology, Innovation, and Partnerships. The American Jobs Plan calls for a further $50 billion investment in NSF, and for the new directorate to focus on fields critical to future U.S. economic competitiveness and national security, including semiconductors and advanced computing, advanced communications technology, advanced energy technologies, and biotechnology. While

more specific funding and organizational details are still to come, this new entity would strengthen NSF's role in U.S. technological leadership. As with this committee's bill, the Board is gratified by the confidence placed in NSF by expanding its role in translation along with increased investment in fundamental research. Both proposals sit squarely in NSF's mission as originally enacted in 1950 of promoting the progress of science and advancing the nation's health, prosperity, and welfare. The agency and Board are ready to answer this call.

Develop STEM talent for America

Talent is the treasure on which America's S&E enterprise and the nation's prosperity, health, and security depend. There is tremendous opportunity for the U.S. to capitalize on the talent that can be found in every state and every demographic group. Today, S&E knowledge and skills matter not only for scientists and engineers engaged in R&D, but also for a range of jobs across the economy, including in the skilled technical workforce. We want to prepare our nation to meet the challenges of the future by building a deeper domestic bench, one that reflects the diversity of our nation and the future of work. NSF is only one piece of the larger puzzle: increasing STEM skills and opportunities for all Americans will require local, state, and federal governments, public and private educational institutions, community organizations, and industry to step up their efforts to provide on-ramps into S&E jobs and improve the attractiveness, equity, and inclusivity of S&E careers in all sectors. It will require improvements in our nation's K-12 STEM educational performance. The Board supports initiatives in the *NSF for the Future Act* that address the serious concerns noted in *Vision 2030*, including those helping to realize the Board's vision of furthering the broad adoption and use of NSF-funded STEM education research where it is most needed – in classrooms.

In the realm of S&E research, NSF is a key developer of talent, annually funding tens of thousands of researchers and students through grants and a variety of programs. To remain the world leader in basic research and innovation, the U.S. – and NSF – must continue to be the home for all those who are driven by scientific curiosity and a spirit of exploration, coupled with a willingness to take risks, to fail and to try again. This emphasis on freedom, imagination, and individual creativity is essential for retaining our position as the world's innovation leader amid competition with nations that are centrally organized.

As we think about talent, the NSB is focusing in particular on addressing the "missing millions", which includes women and members of racial and ethnic groups who remain underrepresented in STEM compared to their proportion in the general population. Attracting and retaining these students requires addressing the barriers and circumstances that drive their choices. To that end, the NSB has hosted external panels over the last year on such topics as the Black experience in STEM, COVID-19 impacts on women in STEM, and roadblocks to STEM graduate student retention, and will have a panel next month on lessons from minority-serving institutions (MSIs) on supporting diverse students. The Board has benefited from briefings from NSF on their programs with HBCUs, on new programs that address discipline-specific demographics, and on plans to provide resources to those most impacted by the pandemic. And the Board, for the first time, has held reciprocal briefings and discussions with the Committee for Equal Opportunity in Science and Engineering (CEOSE), the congressionally mandated advisory committee to NSF.

NSF is uniquely positioned to lead by acting to support students – the current and future engine of our nation's S&E research enterprise. The Board appreciates your attention to STEM talent and the

missing millions. NSB believes there are many promising practices ripe for expansion, ranging from networks and partnerships that scale up effective practices in broadening participation, such as NSF's INCLUDES initiative, to partnering researching-intensive universities with emerging research institutions, since only about a third of underrepresented minority students attend research-intensive universities. The Board also notes the criticality of providing financial support to students, such as with NSF's Graduate Research Fellowships, with a focus on outreach to all regions of the country and historically underrepresented populations. Such outreach is critical because undergraduates from minority serving institutions and emerging research institutions might otherwise be at a disadvantage to their peers at research intensive universities. As existing programs are bolstered and new ones created, there is a need for updated metrics to better understand trends and impact, requiring easier access to relevant data and analytics – a need that Dr. Panchanathan is already working on. The Board will continue to work with the Director and the National Center for Science and Engineering Statistics to collect, analyze, and share data on the workforce, including recently added information on the geographic distribution of the U.S. STEM-capable workforce.

Conclusion

The National Science Board is focused on actions that can be taken today for the U.S. to remain preeminent in S&E and fuel the innovation economy across the nation in the next decade, a future where NSF continues to drive U.S. innovation through research and lead the evolution of the global practice of science and engineering. This future is also characterized by a STEM workforce with increased skills that creates more opportunities for Americans and that closely reflects the nation's geographic and demographic diversity. It is a future where U.S. government, industry, academic and other partners are working in coordination to realize national R&D priorities, solve societal challenges and accelerate the discovery-to-innovation cycle.

For more than 70 years, NSF has embodied Vannevar Bush's vision, funding ground-breaking basic research across every field of science and engineering. NSF has launched and supported individuals whose careers as researchers, educators, entrepreneurs, and innovators are embedded in every sector of our economy. It is on this foundation, and in the context of the three trends that call for urgency, that NSB, in concert with NSF, wants to partner with policymakers and stakeholders, including this committee, to build NSF's future. Thank you, Madam Chair and subcommittee members, for the opportunity to testify before you today.

Ellen Ochoa

Biography

Optical Information Processing
B.S. Physics, San Diego State University
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Ellen Ochoa retired from federal service in 2018 as Director of NASA's Johnson Space Center, which leads the human space flight enterprise for the nation. She is an experienced astronaut, having served as a crew member on four space shuttle missions in a variety of roles including leading onboard scientific activities, operating the robotic arm, and serving as flight engineer during the launch, rendezvous, and entry phases of the mission. Prior to being named Center Director, Dr. Ochoa was Deputy Center Director for five years; she previously led the Flight Crew Operations Directorate, managing the astronaut office and the aircraft operations divisions.

As the first Hispanic female astronaut, Dr. Ochoa has given more than 300 presentations focusing on the importance of a science, technology, engineering, and math education. She has six schools named after her, several books written about her for the K-8 grades and has been profiled in textbooks and on websites geared toward encouraging females and minorities to pursue technical fields. She is the recipient of many awards including NASA's highest award, the Distinguished Service Medal, the Presidential Distinguished Rank of the Senior Executive Service, and honorary doctorates from six universities.

Dr. Ochoa began her career as a research engineer at Sandia National Laboratories and NASA's Ames Research Center. She has three patents in the area of optical information processing and numerous publications in technical journals. She is a Fellow of the American Institute of Aeronautics and Astronautics, the American Association for the Advancement of Science, the National Academy of Inventors and the Optical Society of America.

Elected Chair in 2020, Dr. Ochoa is in her first term on the National Science Board to which she was appointed in 2016. She previously served as Vice Chair from 2018 to 2020.

Dr. Ochoa serves on a number of boards including the Gordon and Betty Moore Foundation. She previously chaired the Nomination Evaluation Committee for the National Medal of Technology and Innovation, served for 10 years on the Stanford University Board of Trustees, and was a member of the Stanford’s School of Engineering Advisory Council and Aeronautics and Astronautics Department Visiting Committee.