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MEASURING WHAT MATTERS: SCIENCE, STANDARDS, AND STRATEGIC COMPETITION

HEARING

BEFORE THE

SUBCOMMITTEE ON SCIENCE, MANUFACTURING, AND COMPETITIVENESS

OF THE

COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION
UNITED STATES SENATE

ONE HUNDRED NINETEENTH CONGRESS

SECOND SESSION

JULY 21, 2026

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ONE HUNDRED NINETEENTH CONGRESS

SECOND SESSION

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MEASURING WHAT MATTERS: SCIENCE, STANDARDS, AND STRATEGIC COMPETITION

TUESDAY, JULY 21, 2026

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

The Subcommittee met, pursuant to notice, at 10:31 a.m., in room SR–253, Russell Senate Office Building, Hon. Ted Budd, Chairman of the Subcommittee, presiding.

Present: Senators Budd [presiding], Young, Moreno, Baldwin, Hickenlooper, and Blunt Rochester.

OPENING STATEMENT OF SENATOR TED BUDD, U.S. SENATOR FROM NORTH CAROLINA

Senator BUDD. Good morning, everyone. I want to thank Ranking Member Baldwin, Chairman Cruz, and Ranking Member Cantwell for helping to convene this important hearing.

For 250 years, the American economy has told a single, consistent story, one of relentless innovation and bold risk-taking and an unmatched ability to turn ideas into industries. The secret sauce in that formula for continued growth and expanded American prosperity is innovation. Throughout our history, particularly since the end of World War II, the U.S. has been the world's foremost laboratory for fundamental science, and we lead the world in turning that research into revolutionary inventions and commercial products.

As our expert witnesses will discuss, the Vannevar Bush model of the Federal Government funding basic research through universities and research institutions has served our Nation incredibly well. However, we have never faced as fierce a competition as we do today.

Earlier this year, China approved its 15th Five-Year Plan for National Economic and Social Development. According to a recent Congressional Research Service report, the PRC's goal is to build self-reliance in areas it currently relies on the United States and Europe by boosting advanced manufacturing with decisive breakthroughs in advanced materials, equipment, machine tools, and high end instruments, and industrial applications of artificial intelligence and robotics. It also calls for building PRC leadership in strategic and emerging sectors and making other decisive breakthroughs in core areas such as biotechnology, semiconductors, and software.

But don't be confused. The PRC's plan is not just about self-reliance, it's an economic and strategic framework for identifying critical supply chains and industries, then systematically stealing intellectual property, heavily subsidizing manufacturing, and eventually dumping products designed to ensure that other countries cannot compete at scale. We've seen this across multiple strategic industries and the breadth and pace is only increasing.

The PRC has joined the U.S. as the only other country to spend more than a trillion dollars annually on research and development. By 2024, the PRC accounted for 30 percent of global research and development flows, while the U.S. share had declined from 39 percent at the start of the 21st century down to 29 percent. We must be clear eyed about the competition that we face and this committee can play a significant role by setting the metrics by which we define scientific success and place the Federal research enterprise on stronger footing.

First, we need to better prioritize outcome-based metrics as a gauge of impact and competitiveness, influencing international standards, leading high impact research, and measuring technology adoption and diffusion are paramount. Additionally, evaluating the strength of public private partnerships and instances of industry funding university research could signal which lines of applied research are most valuable in making the greatest impact.

Second, this committee should look at ways to streamline, focus, and improve agencies under its jurisdiction like the National Institute of Standards and Technology and the National Science Foundation. Dr. Copan, during your time as NIST Director, you authored an important white paper titled, "Return on Investment Initiative for Unleashing American Innovation", which recommended improving tech transfer, strengthening R&D partnerships with the private sector, and improving access to Federal R&D assets for businesses.

Given the PRC's significant focus on standards development, I look forward to discussing ways in which NIST's world class talent in meteorology can be better targeted to enhance U.S. competitiveness in emerging technologies.

Finally, this committee should look carefully at Chinese scientific and intellectual property theft, which significantly undermines American economic dominance and national security. I firmly believe that the U.S. is well positioned to continue to lead the world in the amazing discoveries and breakthroughs that inspire countless young men and women to engage in the science—to engage in science and build the technologies and companies that shape the future.

However, we are at a critical inflection point if we want to maintain and improve that lead. We can help secure that leadership by rethinking the metrics by which we determine success, streamlining our world class science agencies, and looking for ways to further partner with the private sector on shared applied research priorities.

I'd like to recognize Ranking Member Baldwin to deliver opening remarks. Thank you for joining me.

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

Senator BALDWIN. Thank you Chairman Budd for holding this hearing and thank you to our witnesses today for being here.

Chairman Budd and I share a commitment to ensuring America's global leadership in science and in innovation. The Trump administration says it shares that goal, but actions across the Federal Government tell a very different story. Rather than strengthening America's research enterprise to stay competitive and make life saving breakthroughs, at every turn this administration has undermined institutions that make our scientific leadership possible.

The broader context matters for today's hearing. President Trump terminated or froze over $3 billion in grants between the National Science Foundation and the National Institutes of Health. He has continued to illegally pursue efforts to dismantle the Department of Education. He has targeted some of our Nation's leading research institutions through litigation. He revoked over $200 million in previously approved Tech Hub funding. And most recently, he proposed a rule that would empower the administration to weaponize Federal grants for political purposes. He also fired every member of the National Science Board, which is charged with key congressional and oversight roles, including directing key strategic decisions for NSF's future.

Scientific leadership is not inevitable. It is built through sustained public investment and long-term national commitment. It takes funding basic research even when the payoff may be years away. It takes educating and inspiring the next generation of scientists, engineers, and innovators. It takes equipping our national laboratories and research institutions with cutting edge technology and tools they need to succeed.

If we want to ensure that America is a global leader in scientific and technological advancements, we cannot continue to let this administration continue down this path. Congress has both the authority and the responsibility to stand up to this administration when it undercuts science in such a dramatic way. We write the Federal budget. We should be strengthening, not dismantling public education, research institutions, and our national laboratories. We should be expanding and not cutting the investments that fuel discovery, drive economic growth, and keep America ahead of our competitors.

That is how we win the future and I look forward to hearing from our witnesses. Thank you, Mr. Chairman.

Senator BUDD. All right, thank you. I'd like to introduce our witnesses for today. Our first witness is Walter Copan, Vice President Emeritus for Research and Technology Transfer at the Colorado School of Mines. He's also a Senior Advisor and Co-Founder of Renewing American Innovation at the Center for Strategic and International Studies. Under the first Trump administration, Dr. Copan served as Undersecretary of Commerce for Standards and Technology and the 16th Director of NIST.

Our second witness is Dr. Drew Endy, Director of Bio-Strategy and Leadership at the Hoover Institution at Stanford University. Dr. Endy has extensive experience in biosecurity and currently

serves as the Defense Science Board's Emerging Biotechnology and National Security Task Force.

Our third witness is Robert Atkinson, Founder and Senior Fellow at the Information Technology and Innovation Foundation. Dr. Atkinson previously worked as Vice President of the Progressive Policy Institute and directed technology projects at the Congressional Office of Technology Assessment.

Our final witness is Julia Phillips. Dr. Phillips is a Science Policy Advocate. She spent 20 years at Sandia National Laboratories where she led research strategy as Vice President and Chief Technology Officer.

Dr. Copan, you are recognized for 5 minutes. If you would pull that microphone up close and make sure the talk button is on.

STATEMENT OF DR. WALTER COPAN, VICE PRESIDENT EMERITUS FOR RESEARCH AND TECHNOLOGY TRANSFER, COLORADO SCHOOL OF MINES

Dr. COPAN. Chairman Budd, thank you. Ranking Member Baldwin, members of the Committee, and distinguished participants, thank you for the opportunity to testify on these important topics today.

I serve as senior advisor with CSIS, the Center for Strategic and International Studies, as mentioned, and also as the Undersecretary and Director of NIST. I was part of two of the Department of Energy national labs and my experience spans both government as well as academia, in addition industry, multiple startups, and the nonprofit sector as an executive entrepreneur and investor.

China is both a formidable strategic competitor and our major trading partner. We are in a real global contest for technological leadership and the measurements that matter show clearly that the United States must raise its game. Success requires both immediate action to strengthen our research enterprise and a long-term vision for technological dominance.

By design, the Senate is built to focus on the long game. This committee has a unique opportunity and a responsibility to leverage that perspective, placing the U.S. on a generational trajectory to retake and maintain global leadership. Consider, for example, the simple change of having key science agency leaders confirmed for 6-year terms for strategic continuity. Two decades ago, the United States was a clear global leader in science, technology, and innovation. Today, by many internationally recognized measures, China has overtaken U.S. leadership in 57 of 64 critical technology fields including base and production technologies, and has surpassed the United States in total R&D investment.

China should no longer be viewed only through the lens of intellectual property theft, it has become a major technological force with modern infrastructure and a capable science, engineering, and manufacturing workforce. China now leads the world in highly cited top tier research publications and international priority patent families across critical technologies including biotechnology, quantum information, science and technology, robotics, semiconductors, and artificial intelligence.

It has strengthened its own IP system and the protections to counter areas where the United States leads, while substantially

increasing its influence in international standards. Meanwhile, the United States has allowed the strength and enforceability of our intellectual property protections to decline, weakening the global value of American inventions.

Measuring strategic advantage requires more than counting publications, patents, workforce, or dollars spent. It requires an ecosystem view considering the fundamentals and enablers of strategic competitiveness, research and innovation capacity, manufacturing capability, capital, workforce, standards leadership, trusted supply chains, and enforceable IP rights. The CSIS Tech Edge analysis integrates these factors showing U.S. leadership advantages continue in stack and precision technologies.

Achieving the technological dexterity to build ecosystem strengths across multiple technology domains is a strategic national imperative. Public R&D is indeed our great engine of productivity, startup formation, and national competitiveness. But recent disruptions and self-inflicted wounds have slowed our research enterprise and weakened American capacity while our competition is increasingly strong in running this accelerating race.

To translate invention into impact, preserving the integrity of the Bayh-Dole Act is essential. We must modern Stevenson-Wydler, learning from the NIST Green Paper to unleash American innovation and to finally implement the return on investment legislative proposal for effectiveness, speed, and productivity in R&D collaborations.

Our security depends on the reliability and effectiveness of our R&D, intellectual property, standards, manufacturing, and innovation ecosystems. We have much work to do in education, preparing leaders at all levels for building domestic workforce, and also continuing to attract and retain talent globally to strengthen our innovation economy.

We must enforce the rights of American innovators both here and around the world, incentivize participation in standards development, and invest strategically to enable new manufacturing innovation and production capabilities.

International scientific collaboration with both trusted partners and our competitors is a vital strategic asset. It accelerates discovery, expands our talent pool, secures critical supply chains, and projects American leadership. To defend our interests, engagement in global standards and metrology to support trade must be open, fair, and strategically sustained. Navigating intense competition, we must also recognize the profound strategic threat of allowing the rest of the world to dictate global technical standards.

Finally, we must make the U.S. innovation system ever more agile, faster, reducing administrative burdens, modernizing law and practice, and removing barriers to encourage investment. We must defend our innovators at home and abroad against mercantile and malign threats.

Thank you for this committee's important work to secure U.S. science, technology, and innovation leadership for our economic and national security. I look forward to your questions.

[The prepared statement of Dr. Copan follows:]

PREPARED STATEMENT OF DR. WALTER G. COPAN, VICE PRESIDENT FOR RESEARCH AND TECHNOLOGY TRANSFER, EMERITUS COLORADO SCHOOL OF MINES

Chairman Budd, Ranking Member Baldwin, members of the Committee and distinguished participants. It's a privilege to testify on the state of U.S. science, technology, engineering, and manufacturing for our Nation's global economic competitiveness and national security, particularly in relation to China's ascendance.

The state of the great power competition between the U.S. and China is a focus of the work with the Center for Strategic and International Studies (CSIS), where I serve as Senior Advisor for the Renewing American Innovation project. It has been my honor over the past 5 years to lead research and technology transfer at Colorado School of Mines, a top tier U.S. research university rated in the top 3 engineering programs in America. I previously served our Nation as Director of the National Institute of Standards and Technology, for which this Committee has oversight, and prior, with two of the U.S. Department of Energy national labs. My leadership experience spans public and private sectors—as executive, entrepreneur and investor.

Two decades ago, the United States was the undisputed global leader in science and technology, and in driving innovation for economic value. America's research universities and institutions attracted and welcomed the brightest and best talent from around the world to contribute to our science and engineering enterprise, with many ultimately to become citizens and participants in our National prosperity. Today, however, by many internationally recognized measures, America's global leadership position in the majority of critical technology fields has been overtaken by China.[1] By 2024, China surpassed the U.S. in total R&D investment, and, rather than just being considered a perpetrator of IP theft, China has become a globally recognized force through its own strengths and modern built infrastructure for science, engineering and innovation.[2] China is currently seen as leading in 57 of 64 technology categories essential to the global economy, while the U.S. still holds the clear lead in the remaining seven.[3,4]

China now leads in numbers of patents[5] and highly cited top tier research publications in respected journals,[6] having also strengthened their IP system[7] while further seeking to dominate global technology standards.[8] At the same time, the U.S. has allowed the strength of our intellectual property protections to decline[9,10] contributing to a net devaluation of U.S. intellectual properties in global markets.[11] China now dramatically outpaces the U.S and other nations in international priority patent families granted in critical technologies including biotechnology, quantum information science and engineering, robotics, semiconductors and artificial intelligence. China's national focus on standards leadership and IP has further resulted in a substantially increased rate of accepted contributions to international standards by Chinese entities over the past 10 years.[12]

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[1] The State of U.S. Science and Engineering, 2026: *https://ncses.nsf.gov/ pubs/nsbsep20261*

[2] The Power of Innovation: The Strategic Value of China's High-Tech Drive: *https://www.csis.org/analysis/power-innovation-strategic-value-chinas-high-tech-drive*

[3] ASPI's Two-Decade Critical Technology Tracker, *https://www.aspi.org.au/report/aspis-two-decade-critical-technology-tracker*

[4] State of the Science Address: 2026, *https://www.nationalacademies.org/events/113research productivity in critical technology areas a3 https://www.nationalacademies.org/news/2024/06/in-state-of-the-science-address-nas-president-urges-improvements-to-k-12-science-education-in-order-to-strengthen-the-u-s-stem-workforce*

[5] *https://itif.org/publications/2023/01/23/wake-up-america-china-is-overtaking-the-united-states-in-innovation-capacity/*

[6] *https://www.nationalacademies.org/news/2024/06/in-state-of-the-science-address-nas-president-urges-improvements-to-k-12-science-education-in-order-to-strengthen-the-u-s-stem-workforce*

[7] Translating IP Into Revenue: China's Changing Place in the Global IP Landscape: *https://www.csis.org/blogs/trustee-china-hand/translating-ip-revenue-chinas-changing-place-global-ip-landscape*

[8] What Washington Gets Wrong About China and Technical Standards: *https://carnegieendowment.org/research/2023/02/what-washington-gets-wrong-about-china-and-technical-standards?lang=en*

[9] Intellectual Property Rights in the U.S.-China Innovation Competition: *https://www.csis.org/analysis/intellectual-property-rights-us-china-innovation-competition*

[10] Losing the Lead: Why the United States Must Reassert Itself as a Global Champion for Robust IP Rights *https://itif.org/publications/2023/06/12/losing-the-lead-why-united-states-must-reassert-itself-as-global-champion-for-robust-ip-rights/*

[11] Intellectual Property Litigation: U.S. Trends in Global Perspective: *https://www.cornerstone.com/wp-content/uploads/2026/06/IP-Litigation-US-Trends-in-Global-Perspective-June-2026.pdf*

[12] China's High-Tech Drive in 10 Charts: *https://www.csis.org/analysis/chinas-high-tech-drive-10-charts*

Measuring the context of strategic advantage in the technology domains that matter to the future of the economy and national security, however, also requires taking an ecosystem view that considers the fundamentals and strategic enablers of competitiveness.[13] The CSIS Economic Security and Technology *Tech Edge* methodology[14] takes into account these ecosystem factors across four distinct technology types based on breadth of application and production complexity. These include:

1. Stack technologies (*e.g.,* biotech, AI and advanced chips, requiring deep capital markets, collaborative research networks, and platform orchestration)
2. Precision technologies (*e.g.,* jet engines and lithography, which demand trusted partnerships and gold-standard certification regimes)
3. Production technologies, (*e.g.,* high-end machine tools, robotics and industrial process automation, which need long-term capital and ongoing workforce training)
4. Base technologies (*e.g.,* rare earth elements, batteries, steel and aluminum alloys, which require coordinated supply chains and processing infrastructure)

This analysis indicates U.S. leadership advantage in Stack and Precision technologies, whereas China is increasingly competitive in Production technologies and dominant in Base technologies. In the face of the competition with China, achieving the technological dexterity to build ecosystem strengths across multiple technology types is a strategic imperative for the Nation.

We are now at an inflection point where China's ascendance toward innovation peer status presents America with both risk and opportunity.[15] The U.S. must take a new strategic approach to the future of research and S&E advancement that coordinates across government agencies. We must leverage collaboration and investments with the private sector,[16] bolster education at all levels, and effectively engage our national R&D, intellectual property, standards and innovation enterprise.[17] We have the chance to drive great synergies in our Federal R&D investment through a national S&T and innovation strategy that takes the long view.

At the end of World War II, Vannevar Bush and his seminal report "Science: The Endless Frontier" ushered in a new era of research and innovation for the U.S. America's sustained investment in public-sector R&D has proven to be an essential contributor to our global competitiveness,[18] though its strategic value and high rates of investment return[19] are not always fully appreciated.[20] It is well documented that substantial industrial productivity gains[21] and the majority of our tech startups now originate from public R&D funding.[22,23]

Commencing in 2025, the U.S. R&D enterprise has experienced seismic shifts which have disrupted the pace and continuity of research programs, negatively affecting research productivity, graduate education, international partnerships, innovation outcomes, and more. Current indicators are clear: the pace of progress in priority technologies for the nation, including quantum, biotech and emerging energy has decelerated, affected by grant cancellations, funding slowdowns, staff losses, programmatic discontinuity and uncertainties. America's research and engineering workforce is experiencing its largest loss of talent in history, and other nations are

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[13] Tech Edge, A Living Playbook for America's Technology Long Game—*https://www.csis.org/analysis/tech-edge-living-playbook-americas-technology-long-game*

[14] *https://csis-website-prod.s3.amazonaws.com/s3fs-public/2026-01/260120_EST_Tech_Edge_0.pdf?VersionId=MJKGLWqbgviv53jbBuWHg32poCRpHJAL*

[15] Will America Squander Its New Sputnik Moment? *https://www.csis.org/analysis/will-america-squander-its-new-sputnik-moment*

[16] The State of U.S. Science and Engineering, 2026: *https://ncses.nsf.gov/pubs/nsbsep20261*

[17] U.S. Research and Innovation Performance, Elsevier, 2026: *https://www.elsevier.com/promotions/us-research-and-innovation-performance*

[18] Competing in the Next Economy. Innovating in the Age of Disruption and Discontinuity. A Call to Action: *https://compete.org/wp-content/uploads/coc-disruption_discontinuity-call-to-action-final_12.13.24.pdf*

[19] Federal R&D Funding Is Even More Valuable Than Washington Thinks: *https://www.aei.org/economics/federal-rd-funding-is-even-more-valuable-than-washington-thinks/*

[20] Fieldhouse, A.J., & Mertens, K. (2023). The Returns to Government R&D: Evidence from U.S. Appropriations Shocks. Working paper. *https://andrewjfieldhouse.com/wp-content/uploads/2023/12/The_Return_to_Government_R_D_manuscript.pdf*

[21] *NBER "Estimating the Economic and Budgetary Effects of Research Investments" https://www.nber.org/papers/w33402*)

[22] Dyèver, A. (2024) Public R&D Spillovers and Productivity Growth: *https://www.ecb.europa.eu/press/conferences/ecbforum/shared/pdf/2024/EFCB_2024_Dyevre_paper.en.pdf*

[23] Fleming, L., Greene, H., Li, G., Marx, M., & Yao, D. A. (2019). Government-funded research increasingly fuels innovation. *Science, 364* (6446), 1139–1141. *https://doi.org/10.1126/science.aaw2373*

taking advantage.[24] The OMB's proposed rule to revise the Guidance for Federal Financial Assistance (Docket OMB–2026–0034) has resulted in significant feedback on the future fundamentals of how federally funded R&D will be conducted.[25] Clearly, the U.S. R&D enterprise must move more quickly, align with national priorities, and be good stewards of tax dollars. However, the guidance as drafted would most certainly have the opposite effects, with a cascade of unintended consequences. The nation must learn from its unforced errors, and to avoid delays and disruptions to U.S. research that are particularly costly in view of the accelerating pace of the global innovation race.

To translate invention to impact, preserving the integrity of the Bayh-Dole Act for U.S. innovation is essential.[26,27] We must now implement a much-needed modernization of the Stevenson-Wydler Act to deliver increased innovation outcomes from Federal research, and NIST Green Paper on "Unleashing American Innovation" and the "Return on Investment" Legislative Proposal delivered to Congress in 2020 provide a starting point to achieve these goals.[28] Enabling more flexible and efficient collaborations between universities, government, industry and science philanthropy are key to America's success in S&T across the Nation's innovation ecosystems.[29]

The United States is at a crucial juncture for the future of American innovation leadership globally. Our economic security and national security are closely intertwined with the reliability and the protections afforded by our R&D, IP, standards and innovation ecosystem. The foundational strength of U.S. IP rights, as established by the framers of the Constitution, must be enhanced with the enforceability of the rights of inventors in the U.S. and abroad, together with the rule of law and global respect for private contracts. These are particularly important for standard essential patents (SEPs), where the U.S. still leads the world as a net exporter of innovation. Reliable IP rights licensed to development and manufacturing partners enable trusted global supply chains and value creation for consumers and shareholders alike. The mobile telecommunications sector contributes an estimated total economic value of more than $4.8 trillion to the global economy.[30] Technology innovators, including holders of SEPs, gain returns on their investments in R&D and standards engagement through licenses and royalty payments, in addition to product and services sales. Global intellectual property commerce, driven by SEP licensing, was $1.1 Trillion in 2023, with a net positive balance of trade in intellectual assets to the U.S. of over $130 Billion.[31]

However, there is widespread unlicensed technology use in China of innovations and IP assets owned by U.S. entities. Further, China's government has weaponized its legal system with a wide range of patent and competition law tools, price controls on international entities, forced technology transfers, and by providing selective legal protections and incentives seeking to advantage Chinese companies.[32]

There is a concerning movement away from market-based negotiations and valuation toward government-controlled price regulation for standardized technologies. The EU has proposed a massive new regulatory regime[33] toward government control of SEP prices. The Chinese Communist Party has issued guidelines that would also apply its antitrust laws to SEP licenses to benefit Chinese entities.[34]

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[24] America's Scientific Brain Drain Is No Longer Hypothetical: *https://www.realclearscience.com/articles/2026/07/14/americas_scientific_brain_drain_is_no_longer_hypothetical_1194182.html*

[25] *https://www.science.org/content/article/u-s-researchers-outraged-proposed-changes-federal-grants*

[26] Copan, W.G., America's Goose that Lays the Golden Eggs: *https://rollcall.com/2021/04/22/americas-goose-that-lays-the-golden-eggs/*

[27] Unleashing American Innovation, NIST Green Paper SP1234, *https://www.nist.gov/unleashing-american-innovation/green-paper*

[28] ROI Initiative Status Update: Legislative Package Sent to Congress: *https://www.nist.gov/news-events/news/2020/12/roi-initiative-status-update-legislative-package-sent-congress*

[29] McNutt, M. (2024) Keeping America "Science Strong," *https://pmc.ncbi.nlm.nih.gov/articles/PMC11459151/*

[30] *https://s3.amazonaws.com/media.hudson.org/The+Western+Innovators+of+the+Mobile+Revolution_+The+Data+on+Global+Royalty+Flows+to+U.S.+and+Europe+and+Why+It+Matters+-+Jan+2024.pdf*

[31] Global Innovation Index: *https://www.wipo.int/en/web/global-innovation-index/w/blogs/2025/international-trade*

[32] DOI: *https://doi.org/10.15779/Z38XP6V46N*

[33] *https://single-market-economy.ec.europa.eu/publications/com2023232-proposal-regulation-standard- essential-patents_en*

[34] *https://www.allenovery.com/en-gb/global/news-and-insights/publications/china-draft-sep-antitrust-guideline-released-by-samr-for-public-comment*

Supported by Chinese government incentives, legal actions and long-term strategy, China's technology companies are gaining ground.[35] In the development of 5G wireless broadband standards in the 3GPP (Third Generation Partnership Project) multi-stakeholder consortium, four Chinese companies were in the top 10 list of providing approved contributions to the standard: China Academy of Telecommunications Technology (CATT), China Mobile, ZTE, and substantially led by Huawei;[36] two U.S.-headquartered companies were on this list: Qualcomm and Intel. In 2019, the U.S. placed restrictions on having engagements with those Chinese organizations on the Commerce "entity list." This became a self-inflicted wound for the open technology standards process, damaging the positions of American companies and global partners.[37] We must learn from this experience, among many other lessons, about the strategic importance of maintaining open and fair international engagement for standards, metrology and trade.[38]

Engagement in global collaborations for critical emerging technologies is an essential part of standards development and testing for the U.S. to ensure that common principles are established, and ultimately to support rather than impede the pace of technology innovation. International partnership networks enable the U.S. to establish an effective perspective and the balance between voluntary consensus standards and regulations for innovative new technologies, including artificial intelligence, emerging biotechnologies and quantum systems.

It is essential for the U.S. to provide leadership globally, taking deliberate steps to expand standards engagement and enforce the rights of American innovators here and abroad. We must systemically encourage and incentivize engagement in standards development—for companies large and small, for academia and for government entities. Developing standards literacy as part of U.S. higher education in STEM as well as in economics, business and legal curricula must also be a key priority. As we look to rebuild America's advanced manufacturing base and a trained domestic workforce, as well as trusted, resilient supply chains, the U.S must build upon the strengths of our free market economy, and a reliable intellectual property and innovation system that once again must lead the world.

The future U.S. workforce must have the skills necessary for the STEM-related careers that drive the innovation economy. A prepared workforce is essential for rebuilding and reshoring our advanced manufacturing base for all industries in the economy of the future. The Manufacturing USA Institutes have essential roles to play for the future of America's manufacturing technology base and workforce development. A recent report by the U.S. National Academies provides a wealth of analysis and powerful insights for the future of this manufacturing innovation and support infrastructure to help counter the decline in American manufacturing productivity growth over the past two decades.[39]

America's small-and medium-sized manufacturers are essential parts of the Nation's supply chains and innovation system. Rechartering and fully supporting the Manufacturing Extension Partnership (MEP) in an expanded mission for the U.S. to drive manufacturing innovation, entrepreneurship, shared services and advanced manufacturing technology efficiencies must be considered well by this Committee and stakeholders.

We have much work to do. America's K–12 educational outcomes[40] have fallen behind other nations. Preparing future leaders with modernized higher education pathways and a pragmatic base of experience with flexibility for a range of interdisciplinary career journeys will be essential.[41] Attracting and retaining talented people from other nations also remains vital to our innovation economy.[42] Further,

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[35] *https://www.telegraph.co.uk/business/2024/04/30/huawei-profits-surge-steal-market-share-apple-china/*

[36] China's High-Tech Drive in 10 Charts: *https://www.csis.org/analysis/chinas-high-tech-drive-10-charts*

[37] U.S. drafts rule to allow Huawei and U.S. firms to work together on 5G standards: *https://www.reuters.com/article/technology/exclusive-us-drafts-rule-to-allow-huawei-and-us-firms-to-work-together-on-5-idUSKBN22K214/*

[38] United States Standards Strategy (USSS) 2025: *https://www.nist.gov/standardsgov/united-states-standards-strategy-released*

[39] A Vision for the Manufacturing USA Program in 2030 and 2035: *https://www.nationalacademies.org/projects/DEPS-NMMB-24-01/publication/29295*

[40] U.S. Department of Education Issues Statement on the Nation's Report Card: *https://www.ed.gov/about/news/press-release/us-department-of-education-issues-statement-nations-report-card*

[41] Leadership development in U.S. Higher education: Strategies for lifelong learning and upskilling: *https://www.econstor.eu/bitstream/10419/327649/1/S2444569X2500099X.pdf*

[42] Foreign-born Share of the U.S. STEM Workforce, *https://www.csis.org/analysis/innovation-lightbulb-foreign-born-share-us-stem-workforce*

international scientific collaborations—with like-minded nations who are technology leaders as well as with developing countries in the Global South—enable the acceleration of discoveries, building diplomacy, talent access and supply chain resilience that also supports America's position abroad.[43]

Over the past two decades, the bureaucracy and administrative burdens associated with American publicly funded R&D have also skyrocketed.[44] This bureaucracy has increased the costs and reduced the productivity of U.S. research. We must continually increase efficiencies in S&T across technology domains, drive speed-to-scale for innovation, build interagency coordination, and strengthen intellectual property, technology standards leadership and our international partnerships. The National Science and Technology Council must be fully revitalized for truly effective interagency coordination toward maximizing efficiencies and the value created from public R&E investment. We must further modernize legislation and policies to remove barriers and incentivize innovation for America to continue to lead the world. The U.S. must defend its innovators at home and abroad against mercantile and malign threats.

Thanks to this Committee for your important work toward securing the science, technology and innovation leadership for U.S. economic and national security. I look forward to answering questions you may have.

Senator BUDD. Thank you, Dr. Copan. Dr. Endy, you're recognized for 5 minutes.

STATEMENT OF DR. DREW ENDY, DIRECTOR OF BIO-STRATEGY AND LEADERSHIP, HOOVER INSTITUTION

Dr. ENDY. Thank you, Chairman Budd, Ranking Member Baldwin, members of the Subcommittee, thank you for the opportunity to testify.

I teach and research bioengineering at Stanford. I also direct the Bio-Strategy and Leadership Initiative at the Hoover Institution. I've co-founded companies that build DNA. My wife has left academia to start a company that brews the ingredients going into Narcan and other essential medicines.

I want to acknowledge the work of the National Security Commission on Emerging Biotechnology, chaired by Senator Young. The Commission's work is the best work I've seen in this town on biotechnology. I want to emphasize the Commission's most recent finding. The recommendations from the Commission have been read by Beijing and are being implemented by Beijing. Which brings us to this hearing.

Chairman Budd, thank you again for your framing of the topic. Most topics on competition ask questions like who's in the lead? But you're asking a more important question: How would we know? And so that brings us to measuring what matters.

Let me tell you a story about being in Paris last fall for the Genetic Engineering Olympics I started at MIT over 20 years ago. Five thousand 20-year-olds from all over the world, most now from China. And I found a young gentleman, a 20-year-old from Shanghai, dressed up like a crawfish, this big red costume. I said, what are you doing? He says, well, I'm working on engineering enzymes, bioengineering enzymes to degrade the material in crawfish shells so you could repurpose those materials to make new things like clothing and shielding and stuff like that. I'm like, why? He says, because someday there are going to be Chinese astronauts on

[43] Preserving America's Place in Global Science, T. Smith (2024): *https://nautil.us/preserving-americas-place-in-global-science-1031512/*

[44] Changes in Federal Research Requirements Since 1991: *https://www.cogr.edu/changes-federal-research-requirements-1991*

Mars. And when they're on Mars, they're going to need to have a spicy crawfish soup for lunch. And I want to make sure there's a closed loop crawfish bioeconomy and material manufacturing economy on Mars because it's going to be really important that they have that spicy crawfish soup for lunch so that they remember that they're Chinese on the red planet.

That's what we're competing with. The vibe. The vibe is good in Beijing. How do we measure that? Biology is not like other technologies. Imagine if you could somehow feed your cell phone sand and it would get bigger and bigger and bigger and divide and then you'd have two cell phones. That's what biology does on the regular. That means we don't really know how to measure biology like we know how to measure other forms of emerging technology.

Let me give you an example, more specific. Who's the best in the world at building DNA? DNA is the molecule that includes all of life and it's probably the industrial polymer of the 21st century. Who is the best in the world at building DNA? Nobody in the U.S. Government knows. Not NIST, not the National Science Foundation, not the Department of Energy, nobody I know in intelligence. Huh.

We could answer these questions if we did something about it. If you think about the basic sciences in high school, there's physics and there's chemistry and there's biology. Those are the big ones. And if we think about NIST, NIST has the Physical Measurement Laboratory for physics where we get the kilogram and the meter and the second, right. And NIST has the Material Measurement Laboratory for chemistry and a little bit of biology, but it doesn't have a biomeasurement laboratory yet. Gosh, we could really use one.

There are many things that Congress could do, but getting a biomeasurement laboratory at NIST is, I think, one of the high leverage things that would let us measure what matters and get ourselves in a good position for competing. Don't take my word for it on that one. Your U.S. China Commission last year made getting a biomeasurement laboratory at NIST their number four most urgent recommendation. So it's not just me.

Thanks very much for the opportunity to testify today. I look forward to your questions.

[The prepared statement of Dr. Endy follows:]

PREPARED STATEMENT OF DREW ENDY[1]

MEASURES FOR VICTORY

Securing American Biotechnology Leadership

Testimony[2] presented before the Subcommittee on Science, Manufacturing, and Competitiveness Committee on Commerce, Science, and Transportation

United States Senate

Hearing on "Measuring What Matters: Science, Standards, and Strategic Competition"

21 July 2026

BIOLOGY IS A STRATEGIC DOMAIN

Unlocking biology as a general-purpose technology could add up to a third to our Nation's GDP, make supply chain and manufacturing resilience real for most physical inputs to our economy, help secure Americans and others from biological threats, and create a foundation of optionality underlying economic and political freedom at home and abroad.[3,4] These are not far away or abstract claims made lightly. A mRNA virus took a U.S. Navy carrier out of action earlier this decade. Many essential medicine supply chains can be reshored via leap-frog advances in bio-based manufacturing. A brewing process that makes a medicine can be reprogrammed to make energetics. New World Screwworm could likely be eradicated, not just pushed back, with next generation biotechnology approaches to insect control. And so on.

The sheer number, diversity, and urgency of biotechnology applications make the field more challenging to understand where things stand, and where public investments or governance can make a difference.

BIOTECHNOLOGY WAS BORN HERE

Warren Weaver of the Rockefeller Foundation organized funding for what became molecular biology in the 1930s. His choice mattered because molecules turn out to be the physical level of resolution at which living systems operate and can be reprogrammed or composed.

It then took 40 years of extraordinary basic science until a foundation of knowledge filled in sufficient to unlock the beginnings of modern biotechnology. As one example, restriction enzymes, zinc fingers, TALENs, and CRISPR-Cas systems illustrate a four-decade US-led run advancing foundational tools enabling ever better gene editing and, in turn, everything gene editing enables. DNA sequencing, polymerase chain reaction, DNA synthesis, gene and genome assembly, generative biology, synthetic cell biology, and many more examples can be found of other extraordinarily powerful foundational biotechnology tools that were pioneered and advanced in the United States.

Making real practical applications of modern biotechnology depends on such tools. Recombinant insulin for treating diabetes was made real with first generation gene editing. So were better enzymes for laundry detergents and ice-structuring proteins for low fat ice creams. Because the United States led in the basic science of molecular biology we led in the development of the tools for molecular biotechnology. Because we led the world in developing the tools for biotechnology we developed the world-leading bioeconomy, accounting for 25 percent of biotechnology's global economic impacts. We will lose our lead if we stutter or stumble at all on basic bioscience research or foundational tool development.

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[1] Drew Endy, Ph.D., is the Martin Family University Faculty Fellow in Undergraduate Education (Bioengineering), Science & Senior Fellow (by courtesy) of the Hoover Institution, Core Faculty & Senior Fellow (by courtesy) of the Center for International Security & Cooperation of the Freeman Spogli Institute, and faculty co-director of degree programs for the Hasso Plattner Institute of Design, Stanford University. He is a co-founder and director of Biotic and the BioBuilder Educational Foundation, both 501(c)(3) public-benefit organizations. He is married to Christina Smolke, Ph.D., co-founder & CEO of Antheia, Inc., a biotechnology company that brews ingredients for essential medicines. He serves on the Genesis Mission Subcommittee of the Office of Science Advisory Committee, U.S. Department of Energy, and the Advisory Committee for Variola Virus Research of the World Health Organization.

[2] The views expressed herein are solely those of the author. Nothing in this statement represents a finding, recommendation, opinion, or conclusion of any Committee, Subcommittee, Department, Organization, or Institution the author may be affiliated with.

[3] *https://www.uscc.gov/hearings/made-china-2025-who-winning*

[4] *https://science.house.gov/hearings?ContentRecord_id=6788C987-B83B-4608-9279-281F100FEA9D*

WE UNDERESTIMATE BEIJING ON BIOTECHNOLOGY

When I visited Beijing around 2010, I had dinner with the then Minister of Agriculture. I asked him what he found surprising about China; having "sufficient food and water" was his response. China must feed about four times as many people using less farmland than the United States. I share this anecdote to respectfully suggest that those in Washington DC and other Western capitals may still not fully understand the depth and diversity motivating the practical and sustained urgency behind China's ascendance as a global biotechnology power.

Operational mastery of living matter will provide a platform supporting bottom up and distributed manufacturing of anything bioengineers can learn to encode in DNA. I ask you to not think about biotechnology in the context of existing organisms and natural lineages. Do not limit your thinking to the de-extinction of dire wolves and woolly mammoths either. Ponder what it will mean to become capable of programming the bottom-up self-assembly of complex materials and objects with atomic precision. Ponder what will become the foundations of a deep and structural transformation in our ability to manufacture and transform materials and energy on a planetary scale. Ponder when the beyond astronomical possibilities of what biology could be become accessible to the tools of generative and synthetic biology.

Now imagine President Xi, prioritizing goals that include "complete domestic circulation" of China's economy, to "improve and stabilize" supply chains, to "improve the mix of scientific and technological inputs and outputs," to "ensure harmony between humans and nature," and to "develop a bottom-up (public health) system that ensures early detection, warning, and response so as to control diseases as they arise."[5] Imagine considering and acting consistently over multiple five year planning cycles to advance solutions for provisioning sufficient joules, bits, and atoms for the Chinese people and others. While we chase amorphous self-serving ambitions and change course every few years, Beijing can see the value of seizing the 21st century's "reality engine."

The impacts of Beijing's pro-biotech posture are hard to overstate. There is a joy and enthusiasm for biotechnology throughout China's education, research, and business ecosystems that spill over globally. Last fall while attending the global genetic-engineering Olympics I helped start decades ago, I spoke with a 20-year-old man from Shanghai who was dressed in a crawfish costume. His project was to bioengineer better enzymes for reclaiming and repurposing the materials comprising crawfish shells. I asked him why this might matter. He said that when Chinese astronauts travel to Mars, they will need to have spicy crawfish soup for lunch; he wanted Chinese astronauts on Mars to more readily remember that they are Chinese. Most students in this competition are now from China; some U.S. students even travel to China to find teams to join and compete on. Why? From Shenzhen to Tianjin, biotechnology's vibe is good in China.

WHERE AMERICAN BIOTECHNOLOGY STANDS IN RELATION TO CHINA

My February 2025 testimony before the USCC provided a full stack "snapshot in time" assessment of the then-state of play regarding biotechnology competition.[6] Bottom line up front: the United States has not suddenly gotten bad at biotechnology; rather, we are being overtaken by a more determined, hardworking, and better organized and resourced competitor.

For example, the Shenzhen Institute of Advanced Technology continues to operate as a world-unique, national lab-like facility for research and translation in synthetic biology, announcing in May their leadership of a 10-year Asia-wide initiative advancing synthetic cell research.[7] While an academic colleague in Minnesota announced earlier this month a world-first synthetic cell just barely capable of growth and division, Shenzhen has a 5,000-person team ready to take such work forward with speed and scale.

As another example, in April 2026 Stanford's Center on China's Economy and Institutions reported that, in 2020, China surpassed the United States in the number of clinical trials overall, and in the number of clinical trials for novel medicines in 2023.[8] In 2025, one-third of the pharmaceutical industry's licensing spend went to sourcing new medicines from China.[9] And in June 2026, the US-China Biomedical Competitiveness Scorecard, based on a survey of US-based leaders in industry and academia, reported China and the U.S. are now tied on scientific discovery, China

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[5] *http://en.qstheory.cn/2021-01/14/c_604551.htm*

[6] *https://www.uscc.gov/sites/default/files/2025-02/Drew_Endy_Testimony.pdf*

[7] *https://english.cas.cn/newsroom/research-news/202605/t20260528_1159994.shtml*

[8] *https://sccei.fsi.stanford.edu/china-briefs/china-now-global-drug-innovation-powerhouse-industrial-policy-had-little-do-it*

[9] *https://www.biopharmadive.com/news/china-biotech-drug-licensing-deals-pipeline/758283/*

dominating clinical trials, manufacturing, and supply chains, and the U.S. leading on technology transfer, talent, and finance.[10]

Senator Todd Young put matters plainly last month, stating that "China's biotech strategy is clear, and it's a playbook we have seen before—corner the market, scale the technology, and then strangle supply chains to gain strategic advantages."[11] Senator Young's statement is consistent with what I know; unpublished analysis I reviewed this month suggests China is on track to bring online more new industrial biomanufacturing capacity than the rest of the world combined.

Congress' National Security Commission on Emerging Biotechnology went further, writing, "The CCP is taking action across five key domains of biotechnology prioritization, all of which were included in the NSCEB's April 2025 action plan: National Strategy, Regulations, Infrastructure, Investment, and Data." Restated, Washington and others have been writing the playbooks for biotechnology leadership that Beijing is already reading and running with. They will likely read this testimony too and act accordingly.

BIOLOGY IS THE LAST BASIC SCIENCE TO UNLOCK AS A TECHNOLOGY

Physics and chemistry were the two basic sciences humanity mastered in the 19th and 20th centuries. Biology is following and is already far enough along to matter, yet still not close to realizing its full potential.

Why? Living matter has unique physical properties that are qualitatively unlike those found in the substrates from which other modern technologies are built.

To help make sense of my claim first take a step back. Technologies operate across up to three dimensions: energy, information, and matter (*i.e.,* joules, bits, and atoms). Advances unlock when one dimension is added to the others. A wheel by itself (atoms only) rolls down a hill. A wheel combined with a motor and energy source (atoms and joules) can ascend a grade. Wheels combined with motors, fuel, sensors, and computing (atoms, joules, and bits) can become self-driving cars.

Living matter begins at the intersection of joules, bits, and atoms: photosynthesis (joules), genomes (bits), and ribosomes (atoms that wrangle atoms). The dimensions are intertwined from the start. DNA is information as matter, for example. Even simple living cells are stuffed up to forty percent full of molecules, thousands of distinct kinds. There is still not one natural living cell for which we understand all its life-essential molecules. Each molecule is moving spontaneously due to background thermal energy, colliding randomly with other molecules a billion times a second. Together molecules comprise cells, the fundamental units of life. Cells take simple chemical inputs and make more cells. Each new cell differs slightly from its parent, at random, leading to profound differences over generations. Meanwhile, molecular machines inside cells decode genetic instructions that make molecules from scratch, with atomic precision.

Imagine if the transistors inside your cell phone were all moving around spontaneously. Imagine if you could feed your cell phone sand and it would spontaneously get bigger until, suddenly, you had two cell phones. Wetware is neither hardware nor software. Biotechnology's foundations are the deep frontier.

BIOTECHNOLOGY'S APPLICATION TRAP

From a historical perspective the United States knows well how to advance and translate foundational science into world leading technologies. Lead development of the tools for measurement, modeling, and tinkering sufficient to lead on foundational science and do the science. Lead development of the tools for design, prototyping, and testing sufficient to translate knowledge into world-leading innovations and innovate. Support and give away the preceding via public funding sufficient to enable private sector entrepreneurship, competition, and industry capable of supplying free markets at scale.

A unique challenge in biotechnology has been and remains the urgency of biotechnology's application layer. Imagine being a computer science researcher and only finding support for new mobile phone apps that help patients or doctors tomorrow. Something that takes weeks or months to have impact has no chance of funding. A new programming language, software compiler, or computer operating system would trigger well intended questions of relevance and dismissal—"which of my diseases will your new compiler cure right away?" ask the sponsors.

Ask a different but related question. Why might big biotechnology advances like CRISPR gene editing only occur once a decade or so? Is it because such opportunities are rare? Or is it because the field of biotechnology overdrives research invest-

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[10] *https://wewillcure.com/insights/innovation-index/united-states-vs-china-biotech-scorecard*

[11] *https://www.biotech.senate.gov/press-releases/u-s-vs-chinese-action-against-key-nsceb-recommendations/*

ments with demands of immediate utility, more so than any other field in the history of emerging technologies? My bet is on the latter.

Imagine if ARPA had insisted on immediate utility to the war fighter regarding packet-switching research in 1975.

One underlying difficulty deserves further noting. Democracies answer to voters who, reasonably, want individual returns now or at least soon. Systems not answerable to voters can defer. This additional *"from decision making to returns and accountability"* asymmetry is real and makes biotechnology's application trap still more challenging to navigate. Staying the course will require Congress to fund work whose payoff arrives after the next election.

MEASURING WHAT MATTERS

Start by noting there are different types of competition—converging, diverging, and winner-take-all, for example. In converging competitions falling behind is recoverable; all competitors keep the option of completing the race. In diverging competitions early leads compound; those who fall behind risk being left behind. In winner-take-all competitions the winner's solution becomes the foundation everyone else must build from.

Much of biotechnology's application layer is convergent. Losing the race to develop one drug costs only a single drug. Second-and third-to-market entrants routinely beat the pioneer. But the enabling research infrastructure and translation ecosystem supporting the process of drug development and successful translation to full-scale markets are trickier. Ignored for too long and the capabilities needed to lead in research, manufacturing, and go-to-market sublimate.

Much of biotechnology's discovery and innovation engine is divergent. The reason is that many of the best tools for advancing bioscience and biotechnology are made from biology itself. Just like Hewlett and Packard long ago used electronics to instrument and make better electronics, putting in motion what eventually became Moore's law, discovery and mastery of biomolecules that can be used to control energy, information, and material inside cells become the tools for discovering and mastering the next generation of useful biomolecular tools. Early leads compound.

Finally, as biotechnology fully matures, we should expect that winner-take-most or winner-take-all competitions will emerge. UNIX was developed as a simple operating system with the goal of making computer programming easier. UNIX was developed once, in New Jersey, to the great benefit of the United States. TCP/IP for data-type agnostic packet-based networking and Github for ready reuse and sharing of software code offer similar lessons. Where will the operating system for life at the cellular scale get developed? Who will advance the foundations needed to realize a distributed 'bionet' enabling manufacturing resilience via download-and-grow DNA protocols? Who will host (and control) the content repositories for programming life?

Framed this way we have a better chance of identifying metrics that may be used to guide public investments in emerging biotechnology and hold so-supported programs accountable. Here are twelve representative examples:

(1) Who is the best in the world at building DNA, going from bits to atoms on demand for the polymer of life?

(2) How many life-essential genes of unknown function(s) remain for organisms of greatest practical importance?

(3) How many of the elements on the Periodic Table can we sense, organize, and deploy using biotechnology?

(4) How complex of a genetically encoded system can be bioengineered on demand and shown to work reliably the first time?

(5) How much effort does it take to get a novel biotechnology product prototyped? Who is best at prototyping? How fast are we getting better?

(6) How much effort does it take to get a novel biotechnology product to market? Who is best at bringing new products to market? How fast are we getting better?

(7) Who has the fastest or most efficient biomanufacturing processes, going from feedstock to product at the greatest rates and yields? How far from theoretical performance limits are we?

(8) During the next pandemic, who can best sustain normal operations with the lowest costs and casualty rates?

(9) What fraction of what the United States needs or consumes can be grown in the United States?

(10) What fraction of the global bioeconomy is in or enabled by U.S. biotechnology?

(11) What percentage of people in the United States can read and write DNA? How does our practical bio-literacy level compare to others?

(12) How do Americans feel about biotechnology? How many Americans love biotechnology?

Note that the above metrics tend to be approach or solution agnostic. Most focus attention or select for improvement in tools, workflows, and systems of innovation and translation.

SMARTER PUBLIC FUNDING

The United States should be smarter with how we spend limited public treasure on advancing and securing biotechnology. The most useful change would be to redirect even a modest amount (~10 percent) of application-focused funding towards foundational science, tooling innovation, and workflow improvements. Doing so would help guarantee that the United States maintains or reclaims its leadership position for biotechnology's most critical diverging-type competitions.

Doing so would also require reversing recent trends by which evermore public funding goes towards immediate economic translation; public treasure spent renewing the soil from which the next harvest of scientific discovery and technical invention arrives is well spent.

We should also consider carefully the potential macroeconomic returns from growing our Nation's world-leading position in the global bioeconomy. One presentation last Friday at the public DOE SCAC meeting challenged the United States to grow its direct bioeconomic activities from today's $1 trillion of $4 trillion to $10 trillion of $30 trillion globally within 20 years. Framed this way relatively modest and well managed strategic programs could have extraordinary economic returns.

Finally, we should confront the confusion between academic research carried out by students or postdocs relative to professionally staffed research conducted by corporations or national laboratories. The primary purpose of the former is to produce researchers—students who have become better at science and innovation, who make discoveries and inventions as a bioproduct of their training, and who become professional researchers. The primary purpose of the latter is to get specific tasks done, from the simple to greatest grand challenges. Both types of research, training and directed, are essential to our Nation's security and prosperity.

FREEDOM OF SCIENCE, COMPETITION, & LEADERSHIP

China's biotechnology campuses rival what our Nation built for high-energy physics last century. Bush's *Science, the Endless Frontier* and Fermilab are the same civilizational act. A nation that had just won a war chose to invest in both understanding and utility. The courage to do both is what we now risk losing just as China claims such confidence.

In 1969, when Senator John Pastore asked Robert Wilson whether Fermilab's accelerators would help defend the Nation Wilson replied, "it has nothing to do directly with defending our country, except to help make it worth defending." Wilson could separate the two because our leadership in science and technology was largely uncontested and most frontiers were ours to walk alone.

Such separation is no longer available. In the competition we now face the freedom of American science is not simply part of what makes our country worth defending, it is how we defend it.

China's wager is not that people will obey; rather that a watched people will remain productive, that innovation and surveillance hold together indefinitely. Our counter-wager is that free people discover faster. But a wager is not a strategy. Freedom outperforms only when free people hold the tools—and right now we ask American scientists to win a compounding race with instruments we risk no longer building.

ONE SPECIFIC RECOMMENDATION

In my personal capacity I believe there is one action you could take now that is well-aligned with the structure of biotechnology competition and would matter greatly.

Most American high schools offer three basic sciences—physics, chemistry, and biology. NIST under Commerce has a Physical Measurement Laboratory (PML) for all of physics, and a Material Measurement Laboratory (MML) for all of chemistry. For biology, NIST has just two strong-but-modest bio-related divisions within the MML.

NIST needs a fully resourced Biological Measurement Laboratory (BML) for all of biology.

My request is not new. I asked the U.S.-China Economic and Security Review Commission for such a laboratory in February of 2025, and the House Committee on Science, Space, and Technology in June of 2025.

The Commission agreed. The Commission's fourth most-urgent overall recommendation in its November 2025 report to Congress reads: "Resource the National Institute of Standards and Technology (NIST) to establish a Bio-Measurement Laboratory (BML). The BML should develop, support, and promulgate standards for biological measurements, materials, and models; advance measurement science and tools for biotechnology; and ensure U.S. standards are adopted globally as the foundation of the 21st-century bioeconomy." [12]

A bipartisan group of House members also agreed and introduced the Standards and Calibration for American Leadership in Engineering Biology (SCALE Biology) Act in May 2026.[13] Jurisdiction over NIST rests with this Subcommittee.

Because such a laboratory still does not exist, today I am asking a third time. The case has only grown stronger. The competition is live. Congress can and should enable NIST to build and operate a Biological Measurement Laboratory.

There are many other high-leverage investments that could be made as described in my prior testimony and elsewhere. I would be happy to discuss any of these or others.

Senator BUDD. Thank you, Dr. Endy. Dr. Atkinson, you are recognized, and thank you for wearing some Carolina blue on your necktie.

Dr. ATKINSON. Even if I'm a Carolina blue, I'm still a good person.

[Laughter.]

STATEMENT OF DR. ROBERT ATKINSON, FOUNDER AND SENIOR FELLOW, INFORMATION TECHNOLOGY AND INNOVATION FOUNDATION

Dr. ATKINSON. Thank you Chairman Budd and Ranking Member Baldwin, members of the Committee, thank you for holding this important hearing.

I'm going to try to maybe push the envelope a little bit because the normal debate on science is more money or less money. That's the debate. And while I'm on the side of more, I also think it's time for a fundamental change in the U.S. research system. We need to abandon the dominant paradigm of investigator-led basic research that's been in place since World War II. That model worked great when the U.S. was dominant.

In 1962, the U.S. Government invested more in R&D than the rest of the world combined, business and government. That's one of the reasons why we're dominant today. But that world no longer exists. China invests more in R&D than we do government overall. And we now have an aggressive and capable competitor who can absorb our knowledge. That's one of their core business models, is to absorb our knowledge.

As Chairman Budd said, some of it's by IP theft, but some of it is just going to conferences, reading what we do, and they can turn that basic research or fundamental research into discoveries and that lets them turn it into competitive products. So yes, we need more money, but we also need a new system.

So, what is the current system? Multiple factors, but basically, let me say four. One, is there should be no strings attached, just give the academic researchers money. Basic research is more important than applied. All disciplines are equal, so we shouldn't pick among disciplines and science should be global. That worked in the

[12] *https://www.uscc.gov/sites/default/files/2025-11/2025_Annual_Report_to_Congress.pdf*

[13] *https://mcclaindelaney.house.gov/media/press-releases/rep-mcclain-delaney-announces-new-bipartisan-bill-advance-us-leadership*

past, but it doesn't work now. There are more important—there are disciplines that are more important. Science cannot be global in the same way because now we're facing a core competitor.

And I think there do have to be strings in the sense of we should be looking for certain types of outcomes and accomplishments from our science funding, not just saying, well, we hope something happens. Why is that so important? As Chairman Budd, you mentioned a CRS report that China seeks technological independence and you rightly noted it's more than that, if that's all it was. That's not good, but it's not fundamental.

They're seeking technological dominance in my view at ISTIC. They're seeking to replace our advanced companies with theirs in the most advanced industries. As Xi Jinping stated, "Technological innovation has become the main battleground of the global playing field and competition for tech dominance will grow unprecedentedly fierce." Note the word battlefield and dominance. He's signaling what he wants right there.

I think the evidence now is pretty clear that the Chinese are at least on par with us. They have 3 million researchers, we have 1.7. They had 58,000 articles in high quality natural science and health science journals. We had 36,000. Most interestingly, according to Nature, the new study on the top 25 research universities globally, I bet if I asked anybody in this room, how many does the U.S. have? Maybe 12, 15? We have three. Stanford is on the list but not at the top. The Chinese have 21 of the top 25 research universities globally. And if you did an inverse scoring when the top gets more scored, they are six times ahead of us.

So, what do we need to do? I would argue number one, we need to shift more funding toward applied research. And I don't mean development, I don't mean things companies are doing but what's called the TRL, the Technology Readiness Level. Move it up 1 or 2 from 1 and 2 to 3 and 4. Target funding to national economic power industries. This is what the CHIPS and Science Act did. It said there are 10 key technologies that are important to our future. Great, let's do that.

NSF and other agencies need to take more seriously the national competitiveness component of what they call the broader impacts assessments. You show these other impacts. Look, in reality, competitiveness is not taken seriously. It's a check mark. It's not taken seriously.

I think also another key area is you mentioned metrics. One of the metrics to me is industry co-funding research. I mentioned in my testimony that North Carolina leads the country in that in terms of industry funding of universities at North Carolina. You've got NC State, you've got Duke, Wake Forest, others. That's fantastic. The evidence of that is so clear that you get more startups, more spinoffs, more commercialization for the country.

So, I think one of the things that we could do, very simple thing, would just change—I know we're not on the finance committee but just change the rule for the R&D credit which says if you fund a university and it's basic research, you can get the credit. If it's applied research, it's worse, it's not as good. I don't think that makes any sense anymore. Just make it—if you're funding university research you should get a generous R&D credit.

Last point was, we need to limit access to Chinese from—Chinese access to U.S. scientific knowledge. One easy thing is just prevent or limit Chinese postdocs. Chinese postdocs don't stay here. Chinese Ph.D. students do stay here. Postdocs don't. They come here, they suck it up, they take it back to China. Expand recent guidance on U.S. universities working. NSF has a rule—and I'll just close here—where they say you have to get approval for research universities that are related to dual use technologies—sorry, that are on the U.S. entities list. OK. But why is Tsinghua University, the top university in the world, OK to partner with, but another one that works with the PLA is not OK to partner with? I think just for important technology areas we need to have much more careful oversight.

With that, I thank you for your time, and I'm sorry for going over.

[The prepared statement of Dr. Atkinson follows:]

PREPARED STATEMENT OF ROBERT D. ATKINSON, FOUNDER AND SENIOR FELLOW, INFORMATION TECHNOLOGY AND INNOVATION FOUNDATION

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INTRODUCTION AND SUMMARY

Chairman Budd, Ranking Member Baldwin, and members of the Committee, I am Robert Atkinson. As the founder, former president, and now a senior fellow of the Information Technology and Innovation Foundation (ITIF)—and previously as a project director at the former Congressional Office of Technology Assessment—I have focused on science, technology. and U.S. competitiveness for more than 35 years.

I commend the Committee for your important efforts to assess how well the current U.S. scientific and engineering research system fits the new environment of robust technological and industrial competition with China.

THE NEED FOR CHANGE

Policy usually changes incrementally, as Congress assesses current performance and makes needed adjustments. But at various times in the history of our Republic,

policy has changed in more fundamental ways. When it comes to the U.S. science, engineering, and technology research system ("the research system"), now is the time for such a fundamental change. We need to abandon the dominant paradigm of investigator-led basic research that has been in place since MIT President Vannevar Bush crafted it after World War II. That model worked when the United States was dominant in science and technology. It no longer works in a world where there is much more parity—and, in particular, when we have an aggressive and capable competitor in the form of the People's Republic of China (PRC). The status quo no longer suffices. It is time for a new model.

WHY TECHNOLOGY PRODUCTION MATTERS

Before discussing the need for change and the changes needed, it's useful to put the issue in context. A key source of national wealth and power comes is the technological sophistication of a country's production system. Lagging nations principally produce handcrafts or low-skill assembly products. Many middle-income nations have graduated to slightly more complex manufacturing (*e.g.,* steel and machine production). But the leading edge of technological power now comes from incredibly complex and challenging technologies. Technologies that are extremely difficult to develop and produce at scale.

Take two examples. The first is semiconductor lithography machines, or machines that make semiconductors. A core component in the machines are mirrors made mostly by German firm Carl Zeiss SMT. These mirrors are so precise and smooth that the acceptable surface deviation is 50 picometers (50 trillionths of a meter), which is less than the width of a strand of spider silk. To put that into perspective, a 50-picometer deviation on a mirror that is 450 millimeters wide would be just 0.4 micrometers (0.0004 millimeters) if you were to scale that mirror up to the size of the United States.[1] Second, consider biotechnology, the production of living cells for some purpose, such as curing disease. A single batch of a biotech drug requires up to 13,000 individual process steps and quality-control checks, and the level of allowable imperfections per dose is the equivalent of locating one grain of sand hidden inside an Olympic-sized swimming pool.

While not all advanced technology industries require these levels of sophistication, they all require complex knowledge. As science fiction writer Arthur C. Clarke wrote: "Any sufficiently advanced technology is indistinguishable from magic."[2] Indeed. Just look at your cell phone. It seems like magic.

These kinds of advanced-technology industries depend on many factors for a nation to be globally competitive in them. One, as I will discuss below, is a strong foundation of scientific, technical, and engineering knowledge.

A second factor is the ability to compete on a level global playing field. Advanced technology industries are characterized by high fixed costs compared with marginal costs. That means they must incur very high upfront expenses before they can even produce the first chip, drug dose, or jet airplane. Economists describe such industries as experiencing increasing returns to scale, meaning that each additional unit sold yields a higher rate of profit because average costs decline.

In these industries, survival depends on innovation and scale. And scale, by providing robust revenues, enables further innovation. As such, being able to sell to global markets is critical. Otherwise, costs won't fall, and R&D won't increase. And competitors will gain structural advantages that ultimately can lead to the demise of U.S. firms. Conversely, U.S. sales of advanced goods and services often take market share from Chinese competitors, limiting China's capacity to reinvest and expand. As an example, if sales of China's COMAC jet airplane were limited in the West, then Boeing would have adequate funds to reinvest in the next generation of passenger jets, and COMAC, even with its massive government subsidies, would be slowed down.

THE CHINA CHALLENGE

A strong knowledge base and robust global sales is critical for continued U.S. techno-economic power. It would be one thing if U.S. competitors were NATO members and other close allies. While it would not be good for America, it would not be the end of the world if South Korea took over semiconductors or Airbus took over commercial jets. This is particularly true because these allied, democratic, market-based nations generally do not want to crush the rest of the competition, and for the most part they play by the rules. This means there would still be space for American advanced technology exports.

But China changes everything. First and foremost, as long as it is governed by an avowed Marxist-Leninist party, China will be an adversary intent on dominating advanced industries globally.[3] And unlike the Soviet Union's Gosplan-directed economy, China has embraced just enough capitalism to achieve its aggressive goals.

What are its goals? Perhaps the best analysis comes from Daniel Tobin, Professor of Practice at the U.S. National Intelligence University. In a May 7, 2025, article titled, "The Persistent, Soaring Ambitions of Xi Jinping's 'New Era' for China, Socialism, and the Globe," Tobin analyzed party documents, including Xi Jinping speeches and statements.[4]

He quotes Chinese Leader Xi Jin Ping:

> Since 1992, the CCP's constitution has maintained that: "The general starting point and criteria for judging each item of the Party's work are that it must benefit the development of the socialist productive forces, be conducive to increasing socialist China's comprehensive national power, and help to improve the people's living standards."

The consensus view in Washington is that China just wants to be strong and prosperous, just as any large developing country wants to be. But Tobin disagrees:

> Indeed, while some external observers have rushed to point out that the official translation says a global leader not the global leader, it strains credibility that, already seeing itself as the number two power in the world as measured in computations of comprehensive national power, Beijing's goal could be to work hard for several decades only to remain number two. In specific areas of international competition including economics, science and technology, innovation, and military capabilities, Xi repeatedly talks about "seizing the initiative," and for and the need for China not to miss another historical opportunity to assume leadership. Indeed, a 2021 People's Daily editorial under the pseudonym "Manifesto" ( ), which Beijing has used several times to express the ambitions of the new era, maintains that "Gaining the upper hand in the competition of comprehensive national power is the key to national rejuvenation."[5]

Tobin goes on to argue:

> Xi Jinping, from his first days in office, has continued to underline these arguments for remaining committed to socialism; yet he also returned to the arguments about socialism's inevitable international triumph that had not been emphasized since the Mao era.[6]

What is troubling is that most U.S. foreign policy experts don't seem to take Xi seriously, assuming that he is simply mouthing Marxist-Leninist platitudes for the party faithful. This may be in part because they believe that only countries like North Korea and the former Soviet Union are really Marxists. For them, "socialism with Chinese characteristics" is a slogan the CCP proselytizes to pacify the core party members.

However, as former UK diplomat Charles Barton writes:

> Internally, when promulgating to its members the speeches of Xi Jinping . . . party documents and instructions, the CCP speaks of an ideological struggle between systems in which the People's Republic of China will gain domination over the United States. Externally, its foreign propaganda system derides the notion of a new cold war, and speaks of 'win-win' or 'a community with a shared future for mankind.[7]

Finally, as Xi has stated: "Technological innovation has become the main battleground of the global playing field, and competition for tech dominance will grow unprecedentedly fierce."[8]

CHINA'S INNOVATION SUCCESS

Measuring a nation's innovation success is difficult, largely because there are few valid and internationally comparable measures of actual innovation. However, three types of measures are used: inputs to the innovation process; outputs from the inputs; and outcomes. On many, science and innovation metrics, if not most, China now leads the United States.

Inputs

The principal input measures are R&D spending and production of STEM talent.

- China's expenditures on R&D, (PPP prices), was $1.03 trillion in 2024 compared to the United States' $1.01 trillion.[9]
- China's business enterprise expenditure on R&D (PPP current prices), was $799 billion compared to the United States' $782 billion.[10]
- China has 3 million full-time equivalent researchers in 2023 compared to the United States' 1.7 million.[11]

- When looking at the top 2,500 businesses in terms of R&D spending and controlling for researcher costs, U.S. firms invested just 13 percent more than Chinese firms in 2024. However, when excluding biopharmaceuticals and software, where the United States is the strongest, Chinese firms invested 6 percent more than U.S. firms, with China investing at least 75 percent more than U.S. businesses in industrial engineering, electronic and electrical equipment, and alternative energy.[12]

Outputs

The principal output measures are publication counts, patent filings, clinical trials listed, and quality of research institutions.

- Articles published in high-quality natural-science and health-science journals: China had 58,532 articles compared to the United States' 36,860 from March 2025 to February 2026.[13]
- Chinese AI publications accounted for 20.6 percent of all AI citations in 2024, with the United States at 12.6 percent.[14]
- In 2024, China accounted for 17.8 percent of AI publications globally while the United States accounted for just 7.3 percent.[15]
- From 2014 to 2025, China's share of highly cited researchers globally rose from 4 percent to 20 percent. The U.S. share declined from 53 percent to 37 percent.[16]
- For the number of highly citated AI publications in the top 100 journals, the United States scored 46 and China 41.[17]
- In 2025, there was 3.9 times more venture capital investment in China than the U.S. (in PPP terms) and 1.9 times more in dollars.[18]
- According to the Australian Strategic Policy Institute, "China is no longer merely leading the research in major technology fields. It's also moving towards a monopolistic position in most of them."[19]
- According the *2026 Nature Index* of the top 25 research universities globally, 21 are Chinese and just three are American. And when scored according to rank (the top university receives a score of 25 and the 25th receives a score of 1), China scores almost six times more than the United States (275 to 47).[20]
- China listed 7,100 clinical trials in 2024, with 6,000 for the United States. Additionally, 37 percent of the licensed molecules produced this year are projected to come from China.[21]
- As of 2022, China produced over 35 percent of the publications in top-tier journals, up from nearly zero in 1980. The United States' share fell from 60 percent to 25 percent. Chinese researchers lead the world in engineering, physical sciences, and materials engineering, but have not yet overtaken the United States in fields such as biomedical and health sciences.[22]
- The Nature Index of publications in leading journals finds that China has 59 percent more than the United States.[23]
- For patents filed under the international patent cooperation treaty (PCT), China filed 73,718 applications in 2025 vs. 52,617 for the United States.[24]

Outcomes

The principal outcome measures include growth of real output in advanced technology industries, technology exports, and productivity growth.

- China holds nearly one-quarter of the global market across 10 advanced industries, and is leading production in 7 of the 10. To match China's advanced industry value-added output as a share of GDP, U.S. advanced-industry output would have to grow by $1.5 trillion.[25]
- China dominates the electric vehicle industry, the steel industry, solar panels, batteries, telecom equipment, chemicals, rare earths, high-speed rail and more. Leading American firms like GE Appliances, IBM's PC business, Lexmark, Motorola Mobility, Magnequench, Cirrus Aircraft and Teledyne Continental Motors, Omni Vision Technologies, and A123 have all been bought by Chinese companies.
- In other cases, U.S. firms such as First Solar, Lucent, Molycorp (rare earths), and 3D Robotics have lost significant market share or exited the market because of unfair Chinese competition.
- China's targets going forward are even more extensive, in consumer electronics, semiconductors, fine chemicals, machine tools and robotics, AI, biotechnology

and quantum computing. And the risk to leading industries in each of 50 states is often significant.[26]

- Of 10 advanced industries, China was ahead of or on par with the United States in innovation on two (nuclear power and EVs and batteries), near the United States on four (robotics, quantum computing, AI and displays) and lagging on four (semiconductors, chemicals, biotech, and machine tools) but making rapid progress on three of these. Another data point: the United States runs an annual trade deficit in advanced technology products with China of $93 billion.[27]
- According to the U.S. Census, the United States in 2024 ran a $69 billion trade deficit with China in advanced technology products.[28]

THE CURRENT U.S. RESEARCH SYSTEM

U.S. science policy has gone through a number of relatively distinct stages. After WWII, when science came to be seen as critical to winning the Cold War and addressing a host of other national challenges, a bipartisan consensus emerged that the Federal government needed to expand its funding of science. But it was not clear what the model should be. On one side was Senator Harley Kilgore (D–WV), who wanted a Federal science agency to advance explicit national goals and purposes. On the other side was scientist Vannevar Bush, who, in his 1945 report to the president, *Science: The Endless Frontier,* advocated for a scientist-led model with individual scientists free to pursue their own interests.[29] With the establishment of the National Science Foundation (NSF) in 1950, Bush's vision prevailed. Bush articulated a linear model of innovation, wherein the Federal government funded basic research and then, through some unexplained process, came commercial innovations. Even though that model has been thoroughly debunked in the science policy literature, it remains the guiding standard for U.S. research policy.[30]

Bush envisioned five key aspects of this system:

1. *There must be significant Federal funding.* By the early 1960s, Federal support for research had reached 2 percent of GDP.
2. *Funding should be merit-based,* going to the best universities and researchers, with no focus on geographic diversity.
3. *There should be no strings.* As Bush wrote, "Scientific progress on a broad front results from the free play of free intellects, working on subjects of their own choice, in the manner dictated by their curiosity for exploration of the unknown."[31]
4. *All disciplines are equal.* If science is to be investigator-led, then government should not favor some disciplines over others. The primary goal is knowledge generation. And all fields are equally capable of producing knowledge. Astronomy is as valuable as computer science.
5. *Science should be global.* Bush wrote that "the Government should take an active role in promoting the international flow of scientific information."[32] The advancement of science benefits humanity, so international collaboration is valued even if the United States is a net exporter of scientific knowledge.

The United States could afford this model because we dominated both scientific research and manufacturing. It wasn't even close. And so, the current science system was established and remains embedded, even as the United States lags dramatically behind world leaders in manufacturing, especially China, and it is struggling to keep pace with China in science.

While science was to be "pure," there was also a realization that science and engineering played key roles in supporting key national missions. Indeed, the dictates of the Cold War meant that certain disciplines, especially physics, engineering, and later computer science, were privileged. This included defense, space, health, agriculture, and energy. These were seen as acceptable areas for government support for not just early stage research but also later-stage development because they were areas the private sector would underinvest in. But unlike most U.S. competitors, including China, national competitiveness was never a mission. That was up to the private sector alone.

The United States has never before faced a techno-economic challenge like it does now with China. The Soviets were a military adversary, but not a techno-economic adversary. China is both. As such, it is time to reconceive and significantly reform the U.S. research system.

IMPLICATIONS FOR FEDERAL POLICY

These changes in the global environment suggest a number of changes are needed in Federal research policy.

More Funding

While the focus of this hearing is on measurement and accountability, it is worth noting that Federal support for R&D has fallen as a share of GDP. It was 1.86 percent of GDP during the height of the Cold War and has fallen to around 0.62 percent. With funding scarce, one option is to tie any new increases specifically to applied R&D in what ITIF calls "national economic power industries."[33]

Some argue that we don't need more Federal investment in research because the private sector will simply fill in the gap. But scholarly research has disproved that idea. Federal funding of science is not a substitute for private sector research; it is a complement.[34] After reviewing over 60 academic articles on whether public sector R&D crowds out private-sector investments, Cockburn and Henderson concluded:

> There are a number of econometric studies that, while imperfect and undoubtedly subject to improvement and revision, between them make a quite convincing case for a high rate of return to public science in this [life-sciences] industry. It is worth noting that there are, so far as we are aware, no systematic quantitative studies that have found a negative impact of public science.[35]

Shift Funding More Toward Applied Research

One way to differentiate between policies and programs is on the basis of what economists call spatial externalities. In other words, domestic policies can have effects beyond the border, either helping or hurting other nations. Some activities, such as basic research, spill over and help other nations. Scholarly research shows that when a country, even one as large as the United States, funds basic research, the majority of the benefits "spill over" to other nations, and they can use that knowledge to help their own economies.[36] In contrast, a larger share of the benefits of applied R&D are retained in the country.

Given this, the rational thing for any country wishing to maximize its welfare is to invest more in applied research while relying on others for basic research results. That is what most countries other than the United States do. They essentially free ride 'on U.S. investment in basic research.

Related to this, other countries target economic competitiveness much more in their R&D funding. According to an OECD study, the United States ranks 34th in out of 36 nations in the share of total Federal R&D invested in industrial production and technology.[37]

For too long, the United States has been doing the responsible thing, and other nations have been doing the "selfish" thing. The United States has long invested significant funds into basic research through agencies like NSF, the National Institutes of Health (NIH), and the Department of Energy (DOE). In contrast, nations like China, France, Germany, Japan, South Korea, and Taiwan devote a significantly larger share of their R&D budgets to applied research to benefit their domestic industries.[38]

For example, most of China's research is later-stage research designed to give its firms advantage. China knows that it can free ride off U.S.-funded basic research. Chinese researchers attend international conferences to hear U.S. researchers present their findings. They subscribe to all the scientific journals that publish results of NSF recipients' work. They send their graduate students and post docs to U.S. universities.[39]

Target Funding to National Economic Power Industries

The science funding system is agnostic about the challenge of national advanced-industry competitiveness. But it no longer makes sense to treat all scientific disciplines the same.

This differentiation was the guiding principle behind the CHIPS and Science Act when it identified 10 key technologies that the government should invest more in. This was a good step, but the effort is underfunded and managed in the NSF TIP program, where it did little to reorient NSF research directorates.

Prioritization will be strongly resisted by the science establishment as they circle the wagons to defend the current system. But these protests should be ignored. For example, the Trump administration's proposal to eliminate the NSF Directorate for Social, Behavioral, and Economic Sciences (SBE) has been widely criticized, but it makes sense as long as the savings are redirected to other key directorates, such as Engineering, Biological Sciences, Computer and Information Science and Engineering, and the Directorate for Technology, Innovation and Partnership.[40]

In addition, Federal policy should give engineering research a larger share of support. Engineering research is critical to global competitiveness. But only about 15 percent of Federal research funding goes to engineering. This should be doubled to at least 30 percent.[41]

At the same time, new funding should be targeted to areas of science, engineering, and technology that have direct implications for national economic power industries.

Finally, NSF and other Federal agencies need to take much more seriously the national competitiveness component in "Broader Impact Assessments" in award review. In 2011, according to the NSF National Science Board, just 17 percent of proposals and reviewers considered competitiveness as an impact, while 45 percent considered increased participation of women and underrepresented minorities as one.[42] The board found:

> Across the four questions, the most common goals and activities were inclusion of women and underrepresented groups; education and training; and public outreach. Pre-K12 focused activities and societal benefits were in the second tier, U.S. competitiveness and partnerships in the third tier, and national security was lowest, with only four mentions across all the responses to the first four questions.

When scientists were asked which topics should be added going forward, the most common one was "social welfare and human health." In other words, competitiveness is window dressing established in the 1980s, when Japan was the foremost challenge, but is not really considered today.

Better Measure Outcomes

The science establishment wants to measure success by how much funding it gets, or at best by articles in peer-reviewed science journals. This is okay only if you want a system with no real accountability.

As such, Federal science agencies need to adopt and use better metrics of success. These can be, for example, measures of transfer of discoveries to the commercial marketplace, as the Association of University Technology Managers publishes every year.[43]

A key measure should be industry funding of university research. It is troubling that the rate of industry funding varies so dramatically. For states, North Carolina, Georgia, and Kansas led in the share of university research funded by industry, and Nebraska, Rhode Island, and Nevada were last. Among institutions, Duke, MIT, and Ohio State led, while University of Maryland, Michigan State, and Pitt were last.[44]

Having strong industry funding pays off economically. There are small, but positive correlations between the share of a state's university research supported by industry and its strength in key innovation variables such as high-tech startups (an R-value of 0.15), venture capital (0.28), high-tech jobs (0.14), and scientists and engineers (0.19).[45] Industry research funding is also associated with stronger university technology output, with a correlation of 0.26 between industry share and academic patents.[46] Moreover, interaction with industry as a STEM graduate student is associated with significantly greater likelihood of producing intellectual property (*e.g.,* patents, invention disclosure, etc.).[47]

As such, Congress should make a number of changes. It should require programs like NSF's Engineering Research Center program to have at least some matching funds from industry as a condition of being awarded funding. Congress should expand the R&D credit for companies that fund university research and eliminate language that restricts the definition of basic research to projects "not having a specific commercial objective."[48] It should broaden the tax credit for energy research consortia to include all research consortia.

Finally, it should make all business funding of university and Federal lab research eligible for a 40 percent flat tax credit. One advantage of these more market-based approaches is that they let industry have more of a say in the kinds of research that is funded, and they better align academia to real-world issues and problems.

Federal funding agencies should tie a small portion of total higher education funding to how well individual universities do at obtaining industry funding for R&D, as some other nations have done. The UK's Research Excellence Framework includes an "impact" component that assesses commercial and societal impact of research, including patents, spinouts, and industry partnerships. Australia's engagement and impact assessment system scores universities on industry engagement, income from industry, and impact case studies. Chinese university funding and researcher evaluation increasingly weight patents, technology transfer, and enterprise partnerships.

Finally, we need to increase the importance of commercialization activities at Federal labs and research institutes. America's Federal laboratories are insufficiently incentivized to invest time, energy, and resources in facilitating technology transfer. DOE lab planning guidance includes a dedicated "Technology Transitions, Commercialization, and Partnership Strategy" section asking labs to describe their CRADA,

ACT, and Strategic Partnerships Projects activities and how these tie into lab strategy. But that's a planning-narrative requirement, not a scored performance criterion on par with the eight goals. It needs to be an enforced performance requirement tied to funding.

More Science and Technology Partnerships With Allies

The China challenge is so large (if part because China has a huge population) that the United States can not hope for success if it does not partner with allies. As such, Congress and Federal agencies need to work to expand joint research initiatives with allies. These activities could include partnering in areas like robotics and aerospace, AI use, and developing a shared network of advanced-industry centers in which firms from both countries can participate in each other's programs, and joint participation in national science programs. A country could qualify for formal participation if it 1) takes steps similar to the United States in limiting knowledge transfer to the PRC, and 2) provides an appropriate share of funding.

Limit China's Access to U.S. Scientific and Technological Knowledge

The U.S. system sees science as a global good, not a weapon in a techno-economic war and so it is lax on restricting PRC access to U.S. technological knowledge. Any new system should work to limit the ability of China to access U.S. knowledge and capabilities. As ITIF has documented, there are a number of steps Congress and the administration should take to limit scientific and technical cooperation with China.[49]

University and Government Research Policies

The framework by which U.S. and Western universities generally govern themselves no longer works. During the Cold War, it was widely accepted that universities should work to limit knowledge transfer to the Soviets. University policies were significantly adjusted to align with national security priorities, spurred by Federal funding and public anxiety.

But with the fall of the Soviet Union, universities and even government research laboratories embraced a globalist vision of knowledge. In this vision, science is a global good. More collaboration is better. And universities, especially private ones, owe little allegiance to the nation, and much to the world as a whole. This is especially true after the declines in Federal and state government support to universities, with most universities now, like most companies, looking out first and foremost for their bottom lines, and not the support of U.S. national techno-economic power.

At the same time, colleges and universities are desperate for revenue, even if that comes from Chinese students, companies, or the CCP. As such, the most important change that needs to happen is for widespread acceptance by U.S. universities that China is an adversary, not a customer. Because of strong incentives for universities to pursue their own self-interest rather than national interest, the Federal government will need to play a stronger role. There are many steps it needs to take.

Congress could start by limiting Chinese nationals from obtaining postdocs at universities and federally funded research and development centers (FFRDCs). Many Chinese nationals obtaining postdoctoral positions in the United States do so after graduating from a U.S. university. And historically, a high share has stayed in America, contributing to the U.S. innovation base and not contributing to China's. But some Chinese nationals come to study as postdocs after graduating in China. Many of them go back to China, and the United States does not benefit. In fact, key knowledge these students acquire in the United States is now used in China.

While NSF does not collect data on the nationality of postdocs, many are from other nations. For example, 55 percent of postdocs at federally funded R&D centers are temporary visa holders.[50] Universities and FFRDCs should be required to report the country of citizenship of postdocs, and the government should track their later decisions to determine whether they stayed in the United States or went back to home countries, especially China. At the same time, where universities and FFRDCs are not able to hire Americans, they should try to hire postdocs from allied nations or non-adversary nations such as India, and not from China.

Congress should ban Chinese funding of U.S. research universities. While China has proved that it can innovate, it often relies on U.S. intellectual property (IP) and research to advance its own national technology innovations. One way it does this is by funding U.S. university research. Chinese-funded research conducted in the United States is taken back to China, hurting U.S. competitiveness. There is evidence that the CCP funds American universities to advance its agenda—and currently there is no robust legal tool to compel recipients to disclose their funding sources.[51]

Congress should make Federal funding of university research contingent on universities not receiving Chinese funding for research.[52] And this ban should also extend to pass-throughs where China funds a U.S. entity that then funds the U.S. research institution.[53] As such, Congress should pass the Defending Education Transparency and Ending Rogue Regimes Engaging in Nefarious Transactions (DETERRENT) Act to expand the oversight and disclosure requirements regarding Chinese funds channeled to U.S. universities and research institutions.

The DETERRENT Act would close loopholes in inadequate reporting and enforcement of Federal laws on university disclosures regarding gifts and contracts from foreign entities.[54] This bill proposes lowering the reporting threshold to $50,000. The DETERRENT Act also would prohibit universities from entering into contracts with a foreign country of concern or with a foreign entity of concern without obtaining a waiver and would hold private research institutions accountable for their financial partnerships by requiring disclosure of concerning foreign investments in their endowments.[55]

Congress should also require disclosure of U.S. faculty research with Chinese researchers related to national power industries. ITIF has reported that PRC espionage is a strategy that extends from state intelligence agencies to nominally private firms, and that Beijing coordinates cyber, human, and corporate channels to steal U.S. industrial and defense technologies.[56] The PRC's espionage ecosystem is aided by the U.S. research environment, which privileges the free flow of ideas and researchers, allowing China to recruit (or coerce) talent trained in America and to have some of this talent engage in IP theft and technology transfer.

A 2024 report from the House Select Committee on the CCP reveals that Georgia Tech received $17 million from an entity affiliated with Tianjin University, while UC Berkeley received nearly $22 million from entities affiliated with Tsinghua University.[57] These contracts were discovered years after they were in place, and both involve advanced research on dual-use technologies. The failure to report is due to weak enforcement of Section 117 of the Higher Education Act. This section requires the disclosure of gifts and contracts over $250,000 from foreign entities. However, the auditing is limited to the Department of Education, and it is possible to obscure the true sources of funding by bypassing funds through intermediaries.[58]

At minimum, universities should be required to disclose in real time all research partnerships with researchers or companies in China. Where those partnerships are with entities of concern in China, People's Liberation Army (PLA) military institutions, or affiliated institutions (*e.g.,* the "seven sons of national defense"), the researchers should be required to first get permission from NSF.

Congress should also approve the Securing American Funding and Expertise from Adversarial Research Exploitation Act of 2025 (SAFE Act) to block U.S. Federal grants to scientists with a history of collaborating with hostile foreign countries, such as China. This bill is drafted in response to a House China Select Committee report that identifies over 50 partnerships between U.S. universities and entities associated with the CCP, including joint degree programs with China's Seven Sons of National Defense—a group of Chinese universities selected to focus on military and defense research and research on sensitive, dual-use technologies such as submarine engineering, aircraft power engineering, and mechanical design, manufacturing, and automation.[59] The SAFE Act would ban federally funded science, technology, engineering, and mathematics (STEM) research by researchers with a history of collaborating with PRC-associated entities, ban DOD funding for universities that partner with adversaries, and, similar to the DETERRENT Act, impose stricter disclosure requirements on collaboration with entities associated with adversaries.[60]

In addition, a 2023 Select Committee on the CCP report outlines further recommendations to "strengthen U.S. research security and defend against malign talent recruitment."[61] Among its recommendations, the report suggests improving cross-agency disclosure guidance produced under National Security Presidential Memorandum 33 (NSPM–33) by NSF. This would require all recipients of Federal research funding, including their personnel and subcontractors, to disclose their relationships with entities and interests with foreign adversaries for a certain period (*e.g.,* the past five years). In addition, the Select Committee, to help agencies in the vetting process, has proposed the creation of "an unclassified database using open-source information to keep track of PRC research entities that engage in defense and military research and civil-military fusion programs."[62] Congress should ban cooperation with CCP/PLA-associated entities and there should be a presumption of research being problematic, and institutions should be required to obtain waivers to proceed.

The National Science Foundation recently announced new guidance for universities on working with parties on the variety of U.S. entities list, prohibiting such partnerships.[63] This is welcome, but frankly a decade overdue. But it does not go

far enough. It makes sense that the PLA-affiliated universities are on an entity list, but what about Tsinghua University and Peking University which are not?

This gets to a key challenge in the entity list system: The listing mechanism is transaction-evidentiary, not capability-based. BIS additions under Part 744 require "reasonable cause to believe, based on specific and articulable facts" tied to a *documented* activity—a specific procurement, a specific lab's involvement in a specific weapons or AI program, a specific export violation. But this is still a legacy of the old system tied to WMD and military capabilities, not broad-based technological competition, and specific cases, not overall institutions. As such, NSF should go further and require universities to receive approval for any research with Chinese universities that is related to dual-use technologies.

Institute Better Screening of Chinese STEM Students

There are vastly more Chinese students studying in the United States than U.S. students studying in China. On the one hand, they gain knowledge here that they can use if they go back. On the other hand, if they stay in the United States (and do not transfer knowledge to China), they are a net plus for the U.S. innovation ecosystem, and conversely, their presence weakens China by reducing talent levels in China. Even if they go back to China, they have been exposed to the U.S. system of freedom and democracy and perhaps would want to support that in China at some point in the future.

However, there are two challenges. The first is that some students return to China. But that does not mean we should cut off flows. If they did not come to the United States, they would likely go to other nations with strong higher education systems, and U.S. research university competitiveness would decline. Moreover, the rate of staying for Chinese STEM students remains quite high. One study finds that, of a sample of 100 Chinese AI researchers studying in the United States in 2019, 87 percent remained in the United States in 2025.[64] However, this is still a relatively limited time period, and we don't know how many plan to return in the next decade. One 2024 study of Chinese students enrolled in U.S. higher ed found that only 43 percent intend to stay in the United States.[65]

At the same time, there is a share of Chinese students who are "bad apples." They pressure fellow Chinese students to toe the CCP party line. They steal U.S. IP. They are closely tied to the Chinese military or intelligence services.[66] Indeed, the porousness between Chinese academic institutions and the PRC government has proven to be an ongoing problem. The United States in 2025 announced that it would start revoking visas of Chinese students with connections to the CCP or studying in critical fields. This should be expanded. Multiple cases have highlighted specific Chinese schools whose students have been linked to the theft of trade secrets and proprietary information. The United States should blacklist these Chinese institutions and reject their students' visa applications.

What is the ratio of "bad apples" to "good"? Is it changing? We do not know. But this should not be a binary choice between limiting or banning Chinese students and opening the doors to all with no assessment. Universities and FFRDCs need to do more due diligence on Chinese STEM students coming here, especially for graduate programs. They need to better monitor for risks of IP theft. The Federal government should require universities to be more transparent: How many Chinese are enrolled in what disciplines? And it needs to provide analytical tools to universities and FFRDCs to make better decisions on individual students.

One of the reasons why universities are so opposed to any limits on Chinese students is that many rely on them as a source of tuition revenue and low-wage research assistance. Given the cuts in state and Federal funding for universities, this is understandable. But all else equal, universities and related programs should try to recruit students from other nations, such as India. Related to this, the U.S. government should pressure foreign fellowship and other tuition assistance programs to not include Chinese students and instead prioritize students from other nations.

Restrict the U.S.-China Science and Technology Agreement

President Jimmy Carter mistakenly furthered opening up to China in 1979, and one step was to sign the U.S.-China Science and Technology (S&T) Agreement. The idea was that by sharing science and technology, China would move into the U.S. orbit and relations would become friendlier. Like so much of U.S. policy toward China over the last 50 years, it was based on wishful thinking and naïveté. China didn't want to become like us. It wanted access to our science and technology to advance its national power.

Over the years, the S&T agreement—a process whereby Federal agencies engage in partnerships with Chinese agencies and scientists—has led to Chinese advances

in national power industries. As a 2014 report from the U.S.-China Economic and Security Review Commission notes:

> In contrast to the U.S. approach of utilizing S&T cooperation primarily as a tool of diplomacy, China uses S&T engagement as a component of a national strategy to build scientific capabilities. This has enabled the rapid development of China's S&T capabilities and threatens the United States' status as the world's leading scientific power. The report also identifies some national security challenges, including the transfer of sensitive technology through espionage and other means that have emerged in the context of bilateral S&T cooperation.[67]

Indeed, proponents of the agreement—who are also proponents of engagement with the PRC—point to cooperation on things such as influenza (which clearly did not work out well, given the fact that China was the source of COVID), birth defects, and air pollution. But they do not mention projects on EVs, agricultural biotechnology, human biotechnology, and nanotechnology, or help with technology standards (which China now manipulates).

When the agreement was last up for renewal, the Biden administration negotiated certain changes, but these had nothing to do with preventing transfer of key knowledge to China.[68] To be sure, there may be areas where cooperation is reciprocal and does not lead to advances in key technology areas supporting Chinese national power industries. As such, the Trump administration should not cancel the agreement. But it should change the agreement to limit it to areas that do not provide China with any assistance in technologies related to national economic power industries. Endangered species research sharing, yes. EV research sharing, no.

CONCLUSION

The world has fundamentally changed in the last decade. The utopian vision of globally integrated, democratic, free-market economies working together in harmony has not materialized. The belief that China could not innovate has proved to be false. And the belief that the United States would continue to lead in advanced-technology innovation and production has also proven to be false.

These new realities require bold reforms in the U.S. research system. Opponents, especially defenders of the university research system, will argue that it's the unfettered pursuit of knowledge that drives innovation and even national competitiveness. They will argue that government can't pick winners. They will argue that all disciplines should be treated equally. That may have made sense in the past. It no longer does.

And they will argue that science will be politicized based on who is in the White House.[69] Indeed, they frame OMB proposals in the Trump administration as "an attack on American science" and claim that the White House will "destroy science."[70] If anything will "destroy" science, it will be reduced Federal funding, coupled with Chinese destruction of U.S. science-based industries.

It is also important to recognize that science has already been politicized; the Biden administration sought to use science to advance its DEI goals. And the idea that the science community has not politicized itself is not borne out by the evidence.[71] A *Nature* magazine editorial stated that "The enterprise of science has been—and remains—complicit in systemic racism."[72] And leading science and tech policy journals, including *Issues in Science and Technology* and the *MIT Technology Review* have taken a turn to the progressive left in recent years.[73]

Meanwhile, the science community is surprised that there is a reaction—perhaps an overreaction—by the Trump administration to this politization of science. Similarly, given the long-standing disregard of the U.S. academic community working with adversaries, including China, is it any surprise that OMB's proposed rule takes a strict approach to limiting cooperation with adversaries?[74] Indeed, the failure of the science community to adequately police itself on matters of both DEI and working with China, not surprisingly has produced stringent regulations in response.

The reality is that neither Democratic nor Republican administrations should politicize science in terms of imposing their ideological views on the enterprise. But before that can happen, the U.S. science enterprise will have to take a hard look at itself and return to objectivity. Even if it does so, which seems unlikely, shifting the science establishment to focus on areas critical to competing with China is not politization of science, unless the science community believes that politization is when democratically elected representatives have priorities for what kind of science taxpayer-funded scientists conduct. The sad reality is that this is exactly what the science community believes.

Thank you for your consideration.

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Senator BUDD. Thank you, Dr. Atkinson. Dr. Phillips, you are recognized for 5 minutes. Thank you.

STATEMENT OF DR. JULIA PHILLIPS,
SCIENCE POLICY ADVOCATE

Dr. PHILLIPS. Thank you very much. Good morning Chairman Budd, Ranking Member Baldwin, and members of the Subcommittee. My name is Julia Phillips. I'm a materials physicist and past leader of research organizations in the private sector and at a DOE National Security Laboratory. The views I am presenting today are my own.

I was a member of the National Science Board for 10 years until April 2026. For six of those years I chaired the board committee that leads the congressionally mandated biennial publication of *Science and Engineering Indicators,* most recently published in May. The report is a policy relevant, policy neutral source of high-quality U.S. and international data. The data tell a sobering story as we've already heard.

While the U.S. has led in science and engineering for over 80 years, its response to the rapid advance of China has been inadequate and we've heard some of that, but there's more. S&T is the new global currency of power. China has pulled ahead of us in important indicators from R&D expenditures to high tech manufacturing. The threat to our future economic prosperity and national security is very real.

The U.S. has become accustomed to the perks that go with being number one in S&E, an outsized influence on the global S&E culture and in setting standards for new technologies. China, as we have heard, does not play by our rules and will have more influence over setting rules as its ascent continues. Absent action, we will not like the outcome.

Federal investments in the S&E enterprise have been key to American success. Taxpayer supported R&D is a balanced public investment portfolio. It supports efforts across a wide range of risk, potential payoff, and time horizon from near-term mission needs to long-term investments in fundamental science with prospects for significant future benefits.

Government-funded basic research is our Nation's seed corn, an investment that has yielded impressive rewards in its contributions to our country's prosperity. This is a unique feature of American S&E and it has paid off handsomely in discoveries that have enabled countless transformative technologies, including today's critical and emerging technologies.

Part of the unique mission of the National Science Foundation is to promote the progress of science through funding, research, and education in all non-medical fields of science and engineering. In addition to providing seed corn, NSF exists to protect our country from scientific and technological surprise, an unanticipated discovery that occurs in another country which could have grave consequences for the U.S.

Chronic underinvesting in this part of the R&D portfolio might save money in the short run, but it reduces future yields, less seed corn for the future economic growth and competitiveness of our Nation. The threats are clear to the U.S. position in S&E. There are

internal threats as well as the external ones, both long standing and newer ones, embodied in new and proposed policy changes. We must address them. Recognizing, preserving, and strengthening key aspects of the culture of science our country led in creating. This is essential for continued leadership at the forefront of discovery.

The U.S. is rapidly approaching a STEM talent crisis cliff. Our K–12 enrollment is falling, students are unprepared to train for STEM jobs at any level, and foreign student enrollment is dropping. World class science requires broad participation in the global scientific community. Some fields require unique facilities built and operated by international partnerships. U.S. scientists need access to them in all fields. Open communication through publication and participation in meetings, collaboration, and dialogue is essential to progress. It decreases the risk of scientific and technological surprise and proposed rules could sharply curtail this pillar of the research enterprise, leaving the U.S. vulnerable.

A hallmark of best in class science is that rigorous peer review is the deciding factor in funding decisions. These decisions, which are made within high level policy guidelines, must be made by experts in the field who cover a range of well-informed approaches. Funding decisions must thus be honored in full to preserve the integrity of the S&E Enterprise.

The U.S. must renew its investments in and commitment to its historic strengths in science and engineering. An open culture, active participation in the global S&E enterprise, a system where the best ideas can compete for resources, and world leading S&E capabilities and talent. It is imperative that those very attributes that made our S&E ecosystem the envy of the world be strengthened and harnessed to create a future that is worthy of our past. Thank you.

[The prepared statement of Dr. Phillips follows:]

PREPARED STATEMENT OF JULIA M. PHILLIPS, PHD

Chair Budd, Ranking Member Baldwin, and Members of the Subcommittee, thank you for the opportunity to submit testimony for this hearing titled, "Measuring What Matters: Science, Standards, and Strategic Competition." My name is Julia Phillips. I spent several decades performing materials physics research and leading research organizations in the private sector and at an NNSA national security laboratory. Let me emphasize that I am commenting in this document and during my oral testimony as a private citizen and reflect my own views. Nothing in this testimony represents the views of Oregon State University.

Between 2016 and April 24, 2026, I was a member of the National Science Board (NSB) and served for six years as the chair of the Board's Science and Engineering Policy Committee. This is the committee of the NSB that leads the biennial publication of *Science and Engineering Indicators,* published under Congressional mandate. The most recent edition of *The State of U.S. Science and Engineering* report was published on May 4, 2026 (*https://ncses.nsf.gov/pubs/nsbsep20261*). The report is a policy-relevant, policy-neutral source of high-quality U.S. and international data. The indicators presented in the report are quantitative representations relevant to the scope, quality, vitality, and evolution of the S&E enterprise.

The summary report, *The State of U.S. Science and Engineering 2026* pulls together data from three thematic reports published between July 2025 and May 2026. The thematic reports cover the three major components of the S&E ecosystem:

- *Discovery: R&D Activity and Research Publications* (*https://ncses.nsf.gov/pubs/nsb20257* published 7/23/2025)—The report covers trends in U.S. R&D performance and funding across the entire spectrum of R&D—basic through applied and on the experimental development—coverage of U.S. Business R&D, Aca-

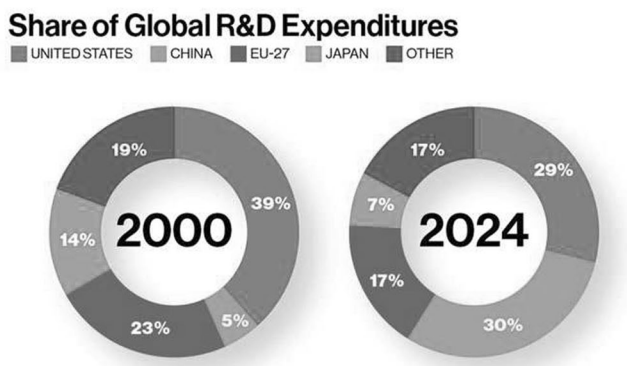
demic R&D, and Federal support for U.S. R&D. The global R&D landscape is also covered, along with worldwide publication output by geography and scientific field.

- *STEM Talent: Education, Training, and Workforce* (*https://ncses.nsf.gov/pubs/nsb20261* published 2/12/2026)—Much of the focus is on the U.S. STEM workforce scale and composition including workforce growth and economic impact, K–12 STEM education performance and challenges, and the higher education STEM pipeline and international competitiveness, including international comparisons.
- *Translation to Impact: U.S. and Global Science, Technology, and Innovation Output* (*https://ncses.nsf.gov/pubs/nsb20262* published 5/1/2026)—The focus of this report is on the translation of discoveries to societal benefit with data on the economic impact of science and engineering activities; innovation, commercialization, and technology transfer; global innovation and patent landscapes; and many aspects of global market dynamics and investment patterns, especially in high tech (knowledge and technology intensive or KTI) industries.

The Emergence of a Peer Competitor

Indicators 2026 places the most recent data in the context of the changes in the S&E ecosystem throughout the 21st Century. The bottom line: China has emerged as a peer competitor after more than 80 years of uncontested American pre-eminence. Other forces are at play, as well. The data tell us:

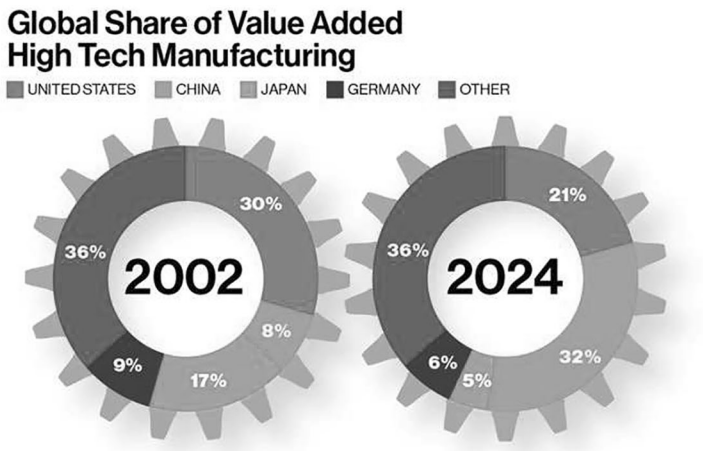
- *R&D Investments:*



Source(s): NCSES, National Patterns of R&D Resources (2023–24 edition); OECD, MSTI, March 2026.

Both the U.S. and China have consistently increased their level of investment in R&D over the course of the 21st Century. Both countries crossed the $1T threshold in 2024, with China at $1.028T and the U.S. $1.009T. The most important point is that China started the century at a MUCH lower rate of investment but has consistently increased its investments by 12–20 percent per year. As a result, China's R&D increased from a 5 percent share of global R&D in 2000 to a world-leading 30 percent in 2024. The Chinese investment trend promises to continue, meaning that the investment gap will widen absent a change in the rate of U.S. R&D investments. Over the same time period, the U.S. share of R&D expenditures declined from 39 percent to 29 percent. By itself, this might not be much to worry about, but there is more.

- *High Tech Industries:*

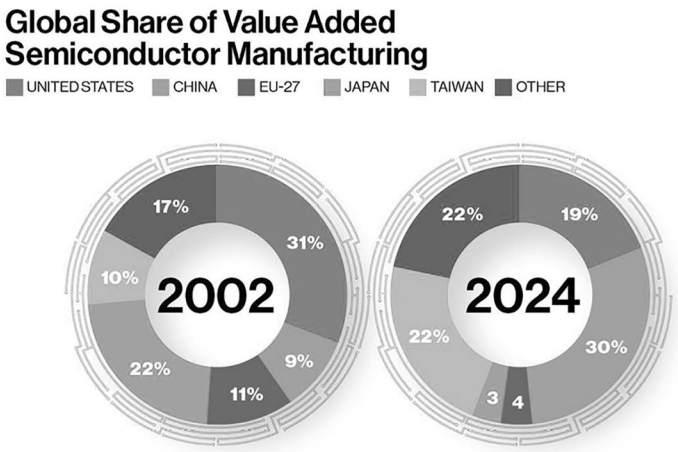


Source(s): S&P Global Market Intelligence, Comparative Industry Service special tabulations, April 2025.

We divide high tech industries into two categories, because the global picture is quite different for the two. For high tech service industries—software publishing and IT and information services industries—the U.S. has dominated to this point, with $1.7 trillion in value added in 2024, and taking a 38–43 percent global share of value added since 2000, primarily led by the software publishing and IT and information services industries. It is important to recognize, however, that these are lagging indicators, and recent announcements suggest that the U.S. lead may be shrinking rapidly in critical areas such as AI.

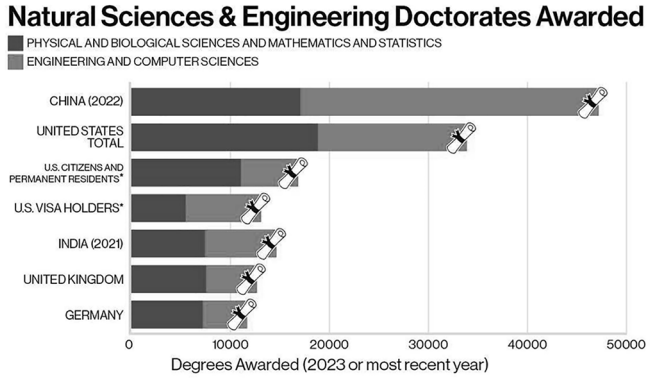
The picture is quite different when one looks at the global picture for high-tech manufacturing where the global distribution has changed dramatically in the first quarter of the 21st century. The figure above shows that in 2002, the U.S. dominated overall with a third of the global share in these industries, while China only had 8 percent share. By 2012, China surpassed the US, and as of 2024, China now controls a third of the world's share at $2.4 trillion in value added. The picture is not uniform across industries, however. The U.S. has the largest share in four industries (air and spacecraft, medical and dental instruments, pharmaceuticals, and weapons and ammunitions). China has the largest shares in the remaining six industries (computer/electronics/optical products; chemicals; motor vehicles; railroad/military vehicles/other transport; other machinery; and electrical equipment). In all industries, these two countries occupy the first and second position. And in some industries, the difference between the two countries is small.

The semiconductor industry is especially important for the building blocks of the digital economy, electronics, critical infrastructure, and advanced technologies across industries like communications, healthcare, energy, transportation, defense and emerging technologies such as AI and quantum computing. The same reversal of dominance that is seen in the metrics for all of high tech manufacturing is apparent, although it might be even worse, given the uncertain future of Taiwan, whose market share also exceeds that of the U.S.



Source(s): S&P Global Market Intelligence, Comparative Industry Service special tabulations, April 2025.

- *Other Leading Indicators of Global Competitiveness:* The economic impact of high tech industries tells a story about the evolution of global leadership that has already occurred. Research expenditures portray the level of aspiration for future attainment in S&E. Other indicators shed light on ongoing changes in S&E leadership.
  - *Ph.D. in STEM fields:* The scientific breakthroughs and technological innovations that will shape the world of tomorrow emerge from the talented and trained people who will carry ideas from the laboratory to the workplace. China produces more PhDs in fields underlying critical and emerging technologies than any other country, especially in engineering and computer science. The U.S. is the second largest producer, but relies on international talent, who are also employed by U.S. industry at higher rates than domestic PhDs. Without visa holders, U.S. production of engineering PhDs would be surpassed by India and computer science PhD production would be surpassed by the UK and Germany.



Source: https://ncses.nsf.gov/surveys/earned-doctorates/2024 August 2025

- *Highly cited scientific publications:* Scientific publications indicate which countries are investing in and publishing work in different fields of S&E. Reviewing

the countries of origin of the most highly cited papers (a measure of "best" papers or those that have significantly influenced subsequent work) shows how the impact of a country's research is changing. The U.S. has long had the highest percentage of its published papers ranked among these important papers (citations fall within the top 1 percent of all papers published in a field). The citation rate for papers with Chinese authors is well below that for U.S. authors but has been increasing steadily for nearly 20 years, while the rate for U.S. papers has been dropping for almost 10 years, most noticeably since 2019. Citation rates for Chinese authored papers in chemistry and engineering actually exceeded those for U.S. authored papers in those fields in 2022.

- *Highly Cited Patents (HCP):* Looking at the evolution of highly cited patents by country is a way of judging the future success of different countries in translating their R&D into economic impact. These are the top 1 percent of all patents cited in subsequent patents in a specific category and year. A higher the share of HCP from a country indicates greater impact of the patents. If we focus on five administration-identified critical and emerging technologies, we see:
  - The HCP share for *semiconductor* patents for inventors from the EU and South Korea was higher in 2021 than in 2010. Conversely, shares for the U.S., China, and Japan were lower in 2021 compared to 2010, although U.S. inventors retained the highest HCP share globally.
  - While shares of *AI* HCP decreased over time for U.S. inventors, they continued to have outsized impact. Impacts in AI for inventors from China changed very little between 2010 and 2021. Impacts increased over time for inventors from the EU and Japan, with Japan emerging just ahead of China to become the 2nd most impactful country in AI innovation.
  - In *nuclear energy,* the U.S. retains a substantial lead in share of HCP, followed by the EU and Japan. China is behind these three nations.
  - *Biotech* is an area of R&D concentration in the U.S., with about 17 percent of private sector research investments directed in this area. HCP shares for biotech inventors from the U.S., China, the EU, and Japan all increased between 2010 and 2021, with Japan accelerating into 2nd place. However, U.S. inventors had the most impact at both points in time.
  - *Quantum information science and technology* forms the basis for potentially revolutionary advances in computation, communication, and sensing bringing huge economic and national security implications. In both 2010 and 2021, inventors from the U.S. produced a disproportional share of HCP in quantum. However, that advantage was much smaller in 2021 as shares from inventors from the EU, Japan, and South Korea increased.

  The trends in HCP do not necessarily mean that the lead in technology and its economic impact has changed hands, but it may indicate the success of a country in translating S&E discoveries into products, which is where societal benefit arises.
- *Benefits of Global R&D Leadership:* There are perks that go with being #1 in R&D. Particularly important among them is the implicit ability to have an outsized influence on the culture in which science and engineering are done and in setting standards for new technologies. We are already seeing erosion in both of those areas and need to reflect on what impact that may have on the lives of our citizens, not to mention the future of our country. China does not play by our rules and threatens to dominate important aspects beyond science output and impact such as standards, establishment of intellectual property, open communication of scientific discovery, commercialization, etc. in ways that would be antithetical to the standards that have propagated through much of the world during the period of U.S. leadership.

Responding to the Challenge of a Peer Competitor

All parts of the S&E ecosystem must respond to the challenge of a determined peer competitor that is committed to dominance. I confine my remarks to the critical roles that basic research and the associated responsibility for STEM (science, technology, engineering, and mathematics) have played in our success over the last 80+ years, what it must contribute to the current challenges we face, and the conditions that must exist for it to succeed. While some of the components of these roles are found across the Federal government and elsewhere in the S&E ecosystem, the *only* organization that has specific responsibility for fulfilling them today is the National Science Foundation (NSF).

The role of the Federal government in the science and engineering (S&E) enterprise is key to the American success story, but the government is far from the larg-

est funder of R&D. The private sector accounted for over 75 percent of R&D investments in 2023 ($709B out of $939B), while the Federal government accounted for about 18 percent ($173B). S&E R&D is funded by over 20 agencies in the Federal government. Six of them (HHS, DOE, NSF, NASA, DOW, USDA) account for 97 percent of Federal support for basic R&D. NSF differs from the others in that the rest perform research in support of the mission of the larger agency, whereas the mission of NSF is research and education in all non-medical fields. In short, S&E research and education across the breadth of disciplines IS the NSF mission.

The Critical Roles of the National Science Foundation in Responding to Peer Competition

The mission of NSF is "to promote the progress of science, advance national health, prosperity, and welfare, and secure the national defense *through funding research and education in all non-medical fields of science and engineering.*" Put another way, *NSF exists so that our country avoids scientific surprise. If something vital for the future is discovered, we know about it.* As I have spoken about *Indicators* over the years, I have referred to basic research and the training of next generation STEM talent as our Nation's "seed corn"—the investment that has more than repaid the initial investments and played an outsized role in the success and impact of our S&E enterprise. This is a unique feature of American S&E—no other nation comes close to matching our level of investment in basic research—and it has played an outsized role in the discoveries that have enable countless transformative technologies, including foundational work leading to AI and Quantum Computing (*https://www.nsf.gov/nsb/publications/2025/NSFAIQ.pdf*). This basic research has led to innovation driving the U.S. economy and helping to secure the national defense.

Basic Research: Basic research focuses on advancing fundamental knowledge about natural or social phenomena. It is primarily driven by curiosity and the desire to understand how things work, frequently with an eye for general areas of technological or societal impact. But the portfolio of Federal R&D investments is very different from those of the private sector. The government invests a much higher percentage—about 25 percent—of its total R&D investment in basic research, whereas the business investment in basic R&D is less than 6 percent of its R&D investment pool.

The type of basic research funded by each sector also differs substantially. The Federal government invests in basic research across the full spectrum of science and engineering. Private sector entities focus on those areas that they judge are most likely to provide breakthroughs that will give them a competitive advantage, leaving broad swaths of S&E uncovered by business R&D. During my time on the National Science Board, we heard numerous stories from leaders in major companies noting that, while they depend on internally funded basic and applied R&D for their competitive edge, that work builds on previous investments in basic science funded by the Federal government.

It is important to note that a basic research agency like NSF has significant differences in scope and time horizons from private business and mission agencies. While the investments are relatively small compared with other Federal agencies or the private sector, they cover *all* areas of non-medical science and engineering and are made for the long term—giving researchers the time and opportunity to pursue knowledge, explore the promise of their ideas, and train future researchers. This is fertile ground for scientific surprise—those discoveries and insights that are unexpected and open the door to unimagined possibilities. Patient investment is critical for many breakthroughs as well as building and maintaining the capability (both physical infrastructures and educated talent) needed to achieve them. Funding for this type of research simply cannot be turned on and off because of changing political winds.

STEM Education and Training: Another significant difference between NSF and other funding entities, either the private sector or other Federal funding agencies, is its emphasis on education and training. NSF is by far the dominant U.S. player in this critical effort. Current events and demographics raise alarm bells about a continuing supply of sufficient STEM talent in the U.S. While we have benefited enormously from foreign S&E talent, the future holds no guarantees. Further, the data show that STEM-oriented jobs have been growing faster than those that do not require these skills—and they pay better. The U.S. needs to double down on preparing the future workforce for STEM careers at all levels—from the skilled technical workforce (those needing relatively short training and licensing beyond high school) to tomorrow's most creative scientists, engineers, and entrepreneurs who may require a decade or more of post-high school education and training.

But students in K–12 are severely underperforming in the basic skills required for any STEM job at any level. Test scores had been stagnating before the pandemic, and recovery since then has not brought performance back even to the mediocre level that was seen in 2019. Student performance in skills and knowledge that are prerequisites to STEM training is also, at best, middling compared with students in other developed countries. To make matters worse, the number of students in K–12 is declining, raising even greater concerns about future STEM talent. Colleges and universities are finding that a very high percentage of entering students are not qualified to take the introductory courses required for many science and engineering degrees, making it impossible for them to complete their education on the usual schedule unless they change their major to a non-STEM subject.

At post-baccalaureate levels of education—the levels acquired by most of the individuals who will go on make the seminal discoveries of the future and/or start companies that are central to the making NEXT critical and emerging technologies real—an extremely high percentage of enrolled students and graduates are not U.S. persons.

The number of international students is starting to slow for a variety of reasons. Proposed ideas include the increased competition for the best students from other countries seeking to emulate U.S. success in S&E and uncertainty about U.S. visa and immigration policies. At the same time, U.S. enrollments are also declining. Part of the challenge is undoubtedly the opportunity cost of pursuing graduate education. These highly qualified students often look at the meager financial support they receive while a graduate student and decide to pursue a career path that offers more immediate financial benefit. Major American universities are admitting 15 percent fewer Ph.D students the last couple of years due to the caution exercised by university departments in the face of extreme uncertainty about the stability of research funding in the wake of widespread challenges to funding for ongoing projects (*https://www.aau.edu/newsroom/leading-research-universities-report/new-phd-admissions-data-show-threat-us-stem-workforce* 7/7/26). It is too early to know whether this is a trend or an anomaly, but it does point out the fragility of the ecosystem.

Requirements for a Productive Research Ecosystem

Open Communication and Collaboration: Threats to open communication of science results with peers and other interested parties, and venues for the intense dialogue and debate about research ideas and results threaten to stifle scientific progress and pose the risk of narrowing the richness of scientific thought and activity. To remain at the forefront of advances in science and engineering, it is essential that top researchers have reliable access to stable sources of research funding to pursue their research, engage with their peers worldwide, both in person and via publication of their peer-reviewed results. It is only through dialogue among experts that ideas can be tested and validated, refined, or refuted, and serve as stepping stones for future advances. Lack of knowledge about other work and collaboration with colleagues globally also increases the risk of scientific and technological surprise—a discovery or development that occurs elsewhere of which we are unaware. Such a surprise can completely upend our ability to compete in the global marketplace or pose a grave threat to our national security. We cannot be vigilant if we do not know what is going on elsewhere and if the best technical minds we have to offer are not allowed access to sufficient information to evaluate what others are doing or thinking about.

The Importance of Curiosity: There must be a place for curiosity in the conduct of research. While problem-driven investigations are critically important and may constitute the majority of many research portfolios, most truly transformative discoveries are made when a researcher has the freedom to pursue the answer to a question that begins, "I wonder what happens when. . .?"

Expert Peer Review Is Essential for Good Funding Decisions: Simply put, we cannot afford to waste money on bad science. Rigorous peer review must be the basis for all decisions about what science is done in a particular area. It is natural for national circumstances and policy to affect the relative distribution of support for different fields of endeavor, but once those decisions are made, decisions about which efforts are to be funded should be made by experts in the field who cover a range of well-informed approaches to the topic. Once funding decisions are made, they must be honored, barring inappropriate behavior on the part of the researcher. The livelihoods of promising young STEM talent depend on having such commitments honored.

Patient Investment in the Best People and Ideas. Since World War II, advancements in science and technology have driven much of our economic growth, underpinned our national security, and transformed nearly every aspect of Americans'

daily lives. New technologies built on federally funded discovery research have led to new businesses, revolutionized health care, and created the mobile, digital world. We must remember that this is a long game. Right now we are competing with China on AI. In 20 years. . .what is next?

Conclusion

The first quarter of the 21st Century has seen a seismic shift in the global S&E landscape. Whereas the global S&E ecosystem was unquestionably dominated by the U.S. for over 80 years, making untold contributions to American prosperity and security, the world now looks very different. The biggest change is the rise of China, enabled by that country's determination to invest year-over-year to level the playing field and, potentially in the not-too-distant future, to surpass U.S. achievements in important ways. The U.S. appears complacent and has not responded robustly, a dangerous posture in the face of a determined competitor. The U.S. must renew its investment in and commitment to its strengths: the openness of its S&E culture; an R&D system where the best ideas can compete for attention and resources; the world's best S&E capabilities that nurture U.S. talent and attract the best and brightest from around the world to contribute to the Nation's success; and long-term investments in understanding the world and creating the future. It is urgent that the those very attributes that made our S&E ecosystem envy of the world be strengthened and harnessed to create a future that is worthy of our past.

Senator BUDD. Thank you, Dr. Phillips. Thank all the witnesses.

Dr. Endy, you mentioned crawfish, but you also mentioned the 5,000-person team in Shenzhen ready to move on in American research accomplishment in biological engineering seemed like that was at speed and scales. You also mentioned your support for the creation of a biological measurement laboratory at NIST. So is China applying that scale, speed, and resourcing to metrology work and standard setting?

Dr. ENDY. What I observe is China appears to be building national laboratory scale facilities for the 21st century across all sciences and in particular in biology and biotechnology. They're advantaged in that in starting such an effort, they're not burdened by a legacy portfolio. It's easier to build a new house sometimes than renovate an old house. The work that they're capable of doing because of the capacity they have, is significant in the following way.

When I have an idea in biology, I won't know if it works or not until I build it and test it. Let's say I'm interested in an AI tool. If I have an AI tool that generates a string of English, I can quickly judge if that text is good or bad. But if I have an AI tool trained on DNA sequences and it emits, generates novel DNA sequences, what do they do? If I start like TAA, TAC, what does that mean? The only way to really know is to build that DNA and test it and then see what it does and feed that measurement back into the modeling platform to get a better model.

So, if you want to have world leading large language foundation models for biology, we have to have the large language laboratories to go along with it. And so that's the capacity I see being developed in Shenzhen and throughout China to scale the measurement and experimentation and prototyping and tinkering and translation of biotechnology solutions. And we just don't have anything like it. Not in the United States, not in Europe. And so that's what I see.

Senator BUDD. You mentioned it might be easier to build a new house than to renovate an old house. Understood. What are parts of the old house? If we have some of the old house that may need renovating, what are those parts that are difficult to renovate?

Dr. ENDY. Thank you for your question, Chairman Budd. When I look to NIST, I see the great tradition in physics and chemistry and the science of metrology and the culture and spirit of measurement science at NIST .is like no other institution I've encountered. It's a world treasure, a national treasure. The amazing thing about biology is it's operating at the intersection of physics and chemistry and information science and energy science. And so those aspects of NIST, the tradition in physical measurement, the tradition in chemical measurement, are profoundly important to advance bio measurement at NIST.

But don't make the following mistake in my opinion. I saw this at MIT when we started the new biological engineering department at MIT over 20 years ago. Nobody in the engineering school who wasn't already in the department that didn't exist yet wanted a new department, because that would be new competition for funding and new competition for students. Nobody wanted another person at the table competing. and they said they were already doing the biology stuff. They had it taken care of.

That wasn't really true. It became really important to create a new thing so that a new space could fill in and breathe and mature over time. That became a new biological engineering department. So, keep, and I would say strengthen the expertise in physical science and metrology, chemical science, and metrology at NIST. The ability of NIST to do an amazing job coordinating industry coalitions and translating innovations into the economy.

But at the same time use that and recognize there needs to be something for biology itself. Biology is a big space. It's 5 percent of our domestic economy and it's poised to grow by a significant amount. Shame on us if we don't figure out how to get a good investment in place for advancing the bioeconomy and a bigger return.

Senator BUDD. What would be some of the consequences if the Chinese biology standards were the globally adopted standards?

Dr. ENDY. Yes. Thank you, Chairman Budd. That's a powerful question. Let me offer the following question in return. What would be some of the consequences if UNIX, the computer operating system, had not been invented in New Jersey? What would be some of the consequences if TCP/IP, the technical standard for packet switching networks, had not been advanced and promulgated by ARPA and NSF?

When we look at the future of biotechnology, biotechnology is not about only the organisms we know and in medicines and stuff like that. Biotechnology is a bottom-up manufacturing platform that will reshape how we build the majority of inputs to our economy.

So, think of a future in which people can partner with biology to solve problems where they are locally. That content for programming the biology is going to have to come from somewhere. It's going to have to be accessible through a bionet, a resilient distributed network for manufacturing on demand. Whether it's medical countermeasures or polymers for 3D printers, anything we can genetically encode.

The platforms for the doing of this, the soft power, the hard power, the economic power, all of that is at stake right now. One of the reasons Beijing has bet big on Bio is not just that they need

it because they need food and everything else, but they also see that the bio race is not yet won. It's pre-ARPANET, it's pre-UNIX, it's open. So that's what's at stake.

Senator BUDD. Thank you very much. Ranking Member Baldwin.

Senator BALDWIN. Thank you all of you for your presence and your testimony.

Dr. Phillips, in April, without notice, the Trump Administration terminated all 22 members of the National Science Board. You had been a member of that board since 2016 and you chaired the Board's Science and Engineering Policy Committee. Can you briefly summarize the critical role that NSB plays in the work of the National Science Foundation and make it your elevator speech? Because I have a follow-up question.

Dr. PHILLIPS. OK. Very briefly, in statute it is stated that the National Science Board has two roles: One is paraphrasing essentially to serve as the Board of Directors for the National Science Foundation, so overseeing strategy, major investments, as well as the portfolio, and at a very high level, appropriate things for operations.

The other is to advise the President and Congress on the state of science and engineering in a global context. And that is the context in which Science and Engineering Indicators is published. There is no Department of Science in the U.S. Government that is different from most other countries. And so, this is sort of a Department of Science role and it expands far beyond NSF.

Senator BALDWIN. Thank you. So, I understand the Trump administration removed members of the National Science Board just before you were set to release a congressionally mandated report on American science and engineering. And I'm deeply concerned about the chilling effect that removals of the board members will have and how removal of the board will limit oversight efforts. So how will the work on NSF be impacted without a board being in place?

Dr. PHILLIPS. Well, that's a good question. And a lot of it probably lies in the details. I will say that that report on Science and Engineering Indicators was published in May because there had been a favorable vote by the board to release it. So that was released. And so for 2026, we're OK.

But going forward and actually in reality, the way the board had been forced to function for more or less the last year, was in the absence of information. We never saw the budget that was submitted to Congress, and we were not informed about other things that the Board had engaged on in the past having to do with serious science issues, facility operations, and things like that, that are arguably the role of the Board to keep an eye on. And it was impossible to get a good amount of that information.

It was hard to tell where that block was coming from. My personal opinion is it was likely not coming from within NSF itself, but it existed.

Senator BALDWIN. Thank you. When China makes a sector a strategic priority, it can achieve global dominance in that space if left unchecked. And we cannot let China achieve dominance in biotechnology, which is so critical to our public health, our economic strength, and national security.

Wisconsin is a national leader in the biohealth industry due to our investments in strong research institutions, advanced manufacturing, workforce training, and industry partnerships. And this important work includes our Biohealth Tech Hub, which consists of a consortium led by BioForward that focuses on personalized medicine and advancing the adoption of the next generation of theranostics.

I will add that it was the Commerce Committee, with Senator Young's leadership, that passed the legislation that allowed a number of tech hubs to be identified throughout the country.

Dr. Endy, this is sort of a compliment to Senator Budd's last question of you. Can you expand on the dangers of losing our global leadership role in biotechnology to China? And what would a world look like where China leads in biotechnology?

Dr. ENDY. I was privileged to grow up in Pennsylvania, near Valley Forge, while this Nation went on a technology innovation run from genetic engineering to Internet to e-mail, to touchscreens to CRISPR to the generative AI, you name it. If I had grown up in Buenos Aires, I would have looked to the United States and concluded that the United States was magic land, the place where magical innovations come from. What is this faraway place? I simply would have to get there.

The thing that is at risk, in my opinion, to my children and their children is that magic land will not be in the United States, magic land will be in China. That's the big picture. If I think about Wisconsin, I was privileged to study at the University of Wisconsin, Madison for a time as a postdoc in chemical engineering. Remember the Rathskeller, a little bit too well. There's the Center for Forest Mycology Research in Wisconsin. It holds a collection of strains of wood fungus. Are these organisms important? It turns out they are. These are the organisms that take wood and convert wood into other material. It's like a GitHub, a code base for transforming one type of matter into more valuable products.

Right now, we have that in Wisconsin, and we're at risk of losing it. And we're at risk of seeing a future where China hoovers up the genetic resources of the world, refactors them, repackages them, and makes them available as the content kit for the future of biotechnology. Now, the good news is it'll get done and we're going to need it. The bad news is it won't be ours in terms of terms and conditions.

So those are the sorts of things that are at stake, and it's hard to overstate it. And because biotechnology is as diverse as biology itself, the impacts are profound and interwoven throughout all aspects of our economy and our lives and livelihoods.

Senator BALDWIN. Thank you.

Senator BUDD. Senator Moreno, you're recognized.

STATEMENT OF HON. BERNIE MORENO,
U.S. SENATOR FROM OHIO

Senator MORENO. Thank you, Mr. Chairman.

As somebody who was born in Bogota, Colombia, I can tell you people in Colombia still think America is magic land and one will do anything to get here, and certainly there's nobody trying to get into China.

Dr. Atkinson, do you think Chinese automakers are normal market competitors?

Dr. ATKINSON. There's no industry in China that's normal and they're abnormal. One of the reasons why they're so successful is they forced foreign companies to give them their technology if they wanted to sell their vehicles in China, a violation of the WTO agreements. They massively subsidized their EVs. They're not normal.

And I think one of the key factors here is we need to really think seriously about limiting those kinds of imports to the U.S. I don't mind competing. We can compete with a Chinese firm that doesn't get massive subsidies, didn't steal their intellectual property. Fine. That's toe to toe. Good. There's no way, in my view, that American automobile companies can compete with this kind of competition.

Senator MORENO. Thank you for that. And do you think it—would you agree that the U.S. auto sector is one of America's most important economic engines, meaning it has a dual use manufacturing capability? We saw that in World War II. Not only, of course, the factories and what they're capable of producing, but in the times of need where we need to increase our industrial base, those auto plants, uniquely are important.

Dr. ATKINSON. Absolutely. We created a methodology to look at all 930 U.S. industries, and we classified them into defense, dual use, enabling, and nothing. Perfume industry we could—the Chinese could take our perfume industry and who cares? You know, Chinese, actually, the major dominant import for China from us in terms of their share is Christmas tinsels.

But when you look at an industry like the auto industry, which is both dual use and enabling, there is so much talent, there's so much going on there related to metal forming and all sorts of other things. And I think you saw that recently when the Secretary of Defense signed new contracts with them, realizing that our defense contractors can't produce as much as we need in terms of defense material. So, if we lost our auto industry, we would be significantly harmed, in my view.

Senator MORENO. Well, thank you for that. And of course, I think you would agree that once China's subsidized firms are embedded in the U.S. market, it becomes almost impossible to reverse that. I think we're seeing that in Europe. I remember when I was a Mercedes dealer and had other German brands, the Germans would always talk about their country's dominance of the auto industry. And Germans, as a matter of culture, would never purchase anything other than a German car, just societally something that they wouldn't do.

And yet because of Chinese vehicles being allowed with impunity into those markets, Volkswagen, who'd never laid off workers in its entire history, just laid off 150,000 auto workers. What would happen if we allowed something like that to happen in the U.S.? How hard is it to reverse that once that happens?

Dr. ATKINSON. Well, the Germans made a very strategic mistake. Their auto companies had dollar signs or yuan in their eyes and they thought, well, we can keep selling. You're not going to keep selling in China. You could see that and they couldn't see it. And so, they let these Chinese firms in. If we do that, Senator, the point

is exactly right. Let's say American consumers start getting used to buying Chinese cars and you have a dealership network, they're going to keep buying more of them.

And so if we let the Chinese in, in any way, shape or form, in my view, it's going to be extremely detrimental to U.S. companies. You could imagine one of the top—one of the big three going out of business and I think the other two seeing significantly smaller market share.

Senator MORENO. And do you think it's also important to, to limit equity participation among Chinese companies in Western auto brands? In other words, there's this idea of passive shareholders. The idea that I own—I don't—but I own a share in Federal Express, so somehow, I matter to the Federal Express executives. Is it problematic to let that equity threshold get to the point where you have basically over influence in those companies?

Dr. ATKINSON. Absolutely. We've long argued that CFIUS needs to have serious reform and CFIUS is too narrow on, is it a missile or is it something that's related to defense. Look, if we don't—if we allow Chinese companies to take equity in autos or certainly auto suppliers, they're going to gain influence there. They're going to move a lot of the technology to China. I would have a complete ban on Chinese equity in nationally important industries.

Senator MORENO. Well, thank you. Tomorrow in this committee we will take up the Connected Vehicle Security Act. We worked on that. I look at my colleagues here, all supportive. I think it's important to show that we are unanimously behind this. This is not a Democrat or Republican issue. There are lots of things I look at my Democrat colleagues that we can disagree on.

But ensuring that we don't allow what you just described to happen, I think it's just critically important that we get that bill across the finish line, not just to pass it but to pass it unanimously. So, urge my colleagues to support this tomorrow as we do the markup. And thank you, Mr. Chairman.

Senator BUDD. Thank you, Senator Moreno. Thanks for your work on that important legislation. Senator Hickenlooper, you are recognized.

STATEMENT OF HON. JOHN HICKENLOOPER, U.S. SENATOR FROM COLORADO

Senator HICKENLOOPER. Talk about good timing. For someone like me who's not known for timing.

Senator BUDD. Welcome back.

Senator HICKENLOOPER. Yes, thank you, Mr. Chair and Ranking Member for this great meeting. And at various times I've crossed paths with some of these people. Dr. Copan more than anybody, just because he's in Colorado and has his finger in a bipartisan way, in more pies than I think anyone I know. And as close as I can tell, he always has good hygiene. He washes his hands. No one's getting infected from one pie. It's a terrible metaphor. I can't believe—but with Dr. Endy here, I shouldn't have used that kind of a metaphor.

And Dr. Endy I've heard about—just because I have an old guy named Joshua Boger was a few years ahead of me at Wesleyan. And through him I got to know Eric Lander and some of the folks.

And my son just graduated from Stanford, so he has an engineering degree that had a lot of kind of the biological aspects of energy.

Anyway, so I guess I'll start with you, Dr. Endy, and just say that as you guys have all said, research and science and engineering technology is essential to advance our competitiveness in not just artificial intelligence, but all forms of biotechnology, all forms of energy. I mean, so much of the essential fundamental building blocks of our society. We've seen the drop in R&D dropping now below that of China's investment, a significant risk. I think you all talked about the importance of continuity and support on all these levels.

And obviously it's always good to reconsider and look at things, but we want to make sure that we can continue to make sure that breakthrough technologies are born from U.S. investments in basic research. We know that. And using obviously global research as well. The example I've written down here was the research from the NSF in the 70s on human cognition, really help create these breakthroughs in machine learning and intelligence, artificial intelligence.

Back in the 70s, it seemed kind of non-applicable. It wasn't clear where the benefit would come. This is one of the reasons where myself and Senator McCormick are funding the bipartisan Senate Science and Innovation Caucus just to make sure there's still more of us talking about and focusing on this aspect. So, Dr. Endy, how can we balance this need for basic research along with the critically important process of applications?

Dr. ENDY. Thank you, Senator. It's my opinion that the public treasure is best spent on foundational science and engineering research. And I'm concerned over my career we've drifted away from that. The problem that occurs when you get too close to the application layer is the number of applications of technology are infinite and so the requests that come in for money become infinite.

But if you get the foundations right, you get high leverage long-term discoveries that surprise us and you get the investments that translate the foundational science closer to the private sector where those innovations can be picked up and brought to market.

So in my experience, the most important thing to do is to sustain the public funding for foundational science and engineering research and to your comment in passing over longer time scales, because that's where you get the improbable inventions and breakthroughs that profoundly change what becomes possible.

Senator HICKENLOOPER. And I don't think there's anything wrong with balancing entrepreneurship and science. I think I view myself as an entrepreneur, I'm one of—depends on how you measure it, but no more than two or three scientists in the U.S. Senate, which is an appalling fact. There are just very, very few of us now. But science, the curiosity and the discipline of science is very closely correlatable—I was an English major originally so that's a problem—correlates very well. I think science and entrepreneurship are the same benefit and play rewards to that same kind of creativity.

Dr. Copan, while you were director at NIST, you spent years overseeing the foundational work on standards. We've had that discussion a couple times. Open source models now empower startups and small businesses, academic researchers to innovate and yet

they face intense strategic rivalry from global competitors like Chinese open weight models, DeepSeek 4 and Qwen. In your opinion, how should NIST and our national standards bodies measure and benchmark open source AI?

Dr. COPAN. Thanks so much, Senator Hickenlooper for that question. It's the trend that we have to deal with. And I think that looking at the measurements of systems that work and recognizing that open source technology development is part of the global ecosystem, we've seen benefits to the U.S. economy, but we also have seen risks that come in as well.

And so having an institution, including the work that NIST is doing, that can measure, that can understand the vulnerabilities and be able to put in place the right kind of guidance principles to support the safeguards that the economy needs for the future is going to be absolutely essential.

Senator HICKENLOOPER. Appreciate that. And I'm out of time, but I do want to recognize one of my political mentors, even though it's devoutly apolitical, Tom Cech is at the University of Colorado. And if you can handle the politics of a university, you can handle anything. But making sure that when Tom Cech came back to the university, they built a research tower and an entrepreneurial tower side by side so that you can facilitate that without attracting all the capital, keeping much of that capital in basic research. I yield back to the floor. Thank you.

Senator BUDD. Thank you, Senator Hickenlooper. Senator Young, you're recognized.

STATEMENT OF HON. TODD YOUNG,
U.S. SENATOR FROM INDIANA

Senator YOUNG. Well, thank you, Chairman. Thanks to you and the Ranking Member for convening this panel. I want to thank our witnesses. It's good to see Dr. Endy and Dr. Atkinson again. I'm grateful for your work.

As our panelists have testified, China has emerged as a competitor in artificial intelligence, biotechnology, and other what we're calling emerging technologies, critical scientific fields. Today, scientific data is often generated across different labs, research institutions, and companies using different formats and standards. Dr. Endy, how does the lack of consistency and interoperability limit the ability of AI tools to make use of that data?

Dr. ENDY. The simple answer, Senator, is garbage in, garbage out. And if you can't even collect the garbage, you can't even try. So, to get a good foundation model in biology, we need to have the data, and that data needs to be consistent from the source by which it's gathered, from where it's gathered, and the methods by which it's gathered.

And so, the examples where this has worked are with protein structures. Sustained public investment in determining the three-dimensional shapes of proteins, how the atoms are positioned, resulted in data for tens of thousands of protein shapes. That dataset was good enough. You could train an AI model on that that was able to predict millions of protein shapes, and that got a Nobel Prize. And that was because the Congress supported investments

in and obtaining data for the positioning of atoms making up proteins.

The other example, which is the best one we've got, is the sequences of DNA in all the organisms around us. If you read out life's genomes, you can use that to train large language models, not on English, but on DNA. Those are the only two datasets we've got right now that allow us to peer into what's possible with AI and bio converging.

Project Genesis, Dario Gil at the Energy Department, we're having very active discussions about how to scale getting better datasets that feed into the AI algorithms. But if we cannot understand what we're measuring, if we cannot compare one measurement made in one place to another place, in one state to another state, none of this works. So that's what's at stake.

Senator YOUNG. So, if you look at the title of this hearing, "Measuring what matters: Science, Standards and Strategic Competition," sort of a plain vanilla title, but I'll say what is today's garbage by coming up with appropriate standards, could become rocket fuel for our economy, could become the feedstock of technological and scientific breakthroughs and innovation and even geopolitical strength if we're to treat data as the strategic asset it is.

As chairman of the National Security Commission on Emerging Biotech, which Dr. Endy you were kind to mention earlier, and I agree the Chinese are being attentive to our recommendations, I was pleased to introduce S4069, the AI-Ready Bio-Data Standards Act, along with my colleague Senator Luján, so that the United States can start treating biological data as a national strategic asset.

But standardizing biological data and other scientific data and preparing it to be used in AI-enabled sciences is very important, but it's not enough. It's only the first step toward toward modernizing American innovation.

Dr. Atkinson, as Congress contemplates data security, what is our role in ensuring that our scientific data as a national strategic resource doesn't end up in the hands of competitors such as China? And should there be similar security standards for other types of data, like personally identifiable information?

Dr. ATKINSON. I think the most important component is scientific and technical data. They can go to town on that. Personal data is important as well. But if I had to prioritize, I'd do that.

Senator YOUNG. Sure.

Dr. ATKINSON. I think the university community has been, I won't say asleep at the switch, but this is not something they really want to do. This is an imposition on the university community. That's how they look at it. And I think that has to change. There are many, many cases where the Chinese will take our data, move it over there and do amazing things with it and we just have to say no, we're not going to allow that.

NSF recently came out with some rules, OMB. I think we need even stronger rules to limit the amount of data as well as technical knowledge that flows out of our universities. The problem is universities are not incented to do that. They're incented to get money. And if they can get money and partnerships, they'll do that. So I think it's up to the government to impose our view on that system.

Senator YOUNG. As my time expires here, I would also note that it's time for a government to posture itself for the long haul for this AI-enabled age which we have to expect could last for a very long time. And to that end, I've introduced some legislation, the Future of Artificial Intelligence Innovation Act. This would codify the center for AI Standards and Innovation. It would require the Department of Commerce to work with our private sector, our Federal agencies, and our allies to ensure effective engagement in development and use of information standards for AI.

I may be submitting a couple of questions for the record to our witnesses to see if you can affirm the importance of passing this legislation. Mr. Chairman, thank you.

Senator BUDD. Thank you, Senator Young. Thanks for your work on that important area. Senator Blunt Rochester, thanks for your patience. You are recognized.

STATEMENT OF HON. LISA BLUNT ROCHESTER, U.S. SENATOR FROM DELAWARE

Senator BLUNT ROCHESTER. Thank you so much, Mr. Chairman, and to our Ranking Member. And thank you so much to the panelists for this really important and insightful hearing, particularly as we talk about strategic competition and both the vulnerabilities that our country faces and as well as the opportunities. I hope that this also creates a sense of urgency because that's what I've gotten from this panel.

I have to say we are talking a lot in our country about AI, but I was very excited to hear Dr. Copan about the Colorado School of Mines recently launched first in the Nation bachelor's degree in quantum systems engineering. I think I was coupling my excitement of that with what Dr. Endy said about the fact that we need vibes. And so I want maybe the two of you, if you could talk a little bit about going back to basics.

I'm in Delaware. I got a farmer, and he or she wants to incentivize their kid to go to this school, or it's a high school student in Wilmington, our city. Why should they go into this? What is it? How do I explain this to my farmer?

Dr. COPAN. There are great new opportunities——

Senator BLUNT ROCHESTER. And let me just say the reason I'm connecting this, is because it connects to our ability to be competitive and to not be dominated, is that we have a workforce that goes into these fields.

Dr. COPAN. Absolutely agree. And I think this was a huge part of the motivation at Colorado School of Mines is recognizing that educational outreach about the opportunities that matter for the future and connecting people with the emerging innovation economy so they can see themselves in it, providing a pathway, providing an open mind and the information that people and their families need to make decisions about how they're going to be educated and what's the pathway for them to have a successful and prosperous life.

Senator BLUNT ROCHESTER. Dr. Endy, what would you say to my farmer? What the heck is quantum?

Dr. ENDY. There's a deeper question in response that I'd like to surface, and it has to do with freedom. China's bet is that a

watched people will remain innovative over time. Our bet must be that a free people are more innovative. Now what does that mean in response to your question?

Over 100 years ago, the United States built a large number of public libraries and that gave everybody the option of learning. If you change the first letter I in library to the letter A, you get a new word called a labrary. So, let's as an example, imagine rerunning the public library playbook to get 3,000 public labraries in towns throughout the United States of America staffed by, wait for it, librarians. And their job is to help people find options on the frontiers of science and technology, to make those options their own opportunities and to bring those opportunities forward into their local economy, solving local problems. That's the sort of thing that I think in a substantive way begins to address the puzzle you're pushing forward and confronting us with.

Senator BLUNT ROCHESTER. Thank you for sharing that. I served as secretary of labor in Delaware and head of state personnel, but I also lived in China. And so, the notion of making sure we build the workforce, that we have the pipeline is really important to me.

I also want to shift Dr. Endy. Delaware is also home to a world class biopharmaceutical industry and our University of Delaware's National Institute for Innovation and Manufacturing Biopharmaceuticals, also known as NIIMBL, is there. So, I'm particularly interested in the technologies that will shape the future of biotechnology and biomanufacturing.

From your perspective, what advances in sensing, measurement, or instrumentation will empower the U.S. to better compete in biological research and biomanufacturing over the next decade?

Dr. ENDY. We have to get better at measuring biology, modeling biology, and making biology, tinkering, and testing and prototyping, measure, model, make. All of those are of paramount importance. The challenge we've got, and its particular challenge for a democratic society, is that everybody wants the applications of biology delivered right away because the applications are so urgent, starting with human health and disease.

Because of that, we risk underinvesting in the foundational tools that make it easier to measure biology, make sense of it, model it, represent it, and try the new thing. And we need a whole investment across the portfolio of tooling and whoever holds those—the reason Silicon Valley sustains a technology lead is not only because of our venture capital community, it's because we have a culture of tool developers who are always developing the next generation of better tools for prototyping, testing, and making sense of it. If we do not have world leading tools, we will have no chance of being world leading.

Senator BLUNT ROCHESTER. Thank you so much. Mr. Chairman, I will ask Mr. Atkinson a question—Dr. Atkinson, for the record, about our supply chains. It's a big area that we've worked on as a committee and that I'm interested in. And then if I could ask all of you to just share with me, as again, someone who's interested in the workforce, your thoughts on how we can build a stronger quantum workforce as well as STEM workforce?

And I yield back. Thank you.

Senator BUDD. Thank you. Great questions. It's been a great panel. We appreciate your expertise that you've brought today and your testimony as well. I think we all have some questions for the record that we're going to leave with you. So, you didn't know you were going to leave here with homework, but Senators have until the close of business on the 28th to submit those questions for the record. The witnesses will have until the close of business on the 11th to respond to those questions.

This concludes today's hearing. The Subcommittee stands adjourned. Thank you.

[Whereupon, at 11:41 a.m., the Subcommittee was adjourned.]

A P P E N D I X

Response to Written Questions Submitted by Hon. Ted Cruz to Dr. Walter Copan

Question 1. Your experience at NIST gives you a unique perspective on the strategic importance of technical standards. Standards shape markets, determine first-mover advantages, and encode the rules that competitors must follow. China has made standards dominance a centerpiece of its innovation strategy.

a. When the U.S. leads in setting technical standards, what measurable advantages does that create for American companies, researchers, and national security?

b. What do we lose if China shapes the standards for AI, biotechnology, advanced manufacturing, or quantum technologies?

Answer. Dear Chairman Cruz: Thank you so much for these important questions.

a. Standards leadership provides the technological performance targets backed by performance credibility for setting the requirements of global markets. U.S. leadership in the standards process will ensure that technologies and products fromU.S. firms will have the opportunity to access such markets with trusted performance and interoperability. Further, standards leadership is reinforced by the contributions of Standard Essential Patents to the commercial practice of the standard, which provides the opportunity for leadership in intellectual property commerce markets, where the United States continues to have a globally leading position in Standard Essential Patents (SEP) licensing.

As I pointed out in my testimony, the U.S. enjoys a positive balance of trade from the standards leadership of our technology innovators, including holders of SEPs. These companies gain returns on their investments in R&D and standards engagement through licenses and royalty payments, in addition to product and services sales. Global intellectual property commerce, driven by SEP licensing, was $1.1 Trillion in 2023, with a net positive balance of trade in intellectual assets to the U.S. of over $130 Billion.[1]

b. There is an old saying that *"who rules standards rules the world"*—which is sometimes re-stated as *"third-class companies make products, second-class companies make technology, first-class companies make standards."* This mindset is at the strategic core of Chairman Xi Jinping's global technology and governance aspirations, shifting China's focus from manufacturing dominance to defining the technical blueprints of future industries. China's stated goal in the "China Standards 2035" initiative is to institutionalize Chinese technical specifications as the default global standards for emerging sectors. By 2035, it seeks to significantly enhance national standardization and the competitiveness of advanced industries, and to position China to lead global competition over technology standards in fields ranging from 6G, the Internet of Things, artificial intelligence, quantum technologies, semiconductors, biotechnology, fusion and renewable energy. By rewriting the rules and establishing new standards governance, China intends to bypass Western nations in international bodies like ISO and IEEE, to ensure that their domestic companies can win. In such a new global order, China's economy and companies would have the advantage over the U.S. and other nations. If the U.S. loses leadership in defining the very technical standards that drive market share for U.S. firms, more Chinese products would flood the market, our positive balance of trade in intellectual assets would erode, the value of U.S. firms and stock markets would decline, and the U.S. economy would shrink.

As mentioned in my testimony, the U.S. itself contributed to this problem, in what I described as a "self-inflicted wound" in 2019 by trying to exclude China from the global 5G broadband standards process in the 3GPP and restricting U.S. firms from

[1] Global Innovation Index: *https://www.wipo.int/en/web/global-innovation-index/w/blogs/2025/international-trade*

engaging in standards negotiations with Huawei, ZTE and other companies[2] on the Commerce Entity List. This damaged the positions of American companies and global partners—and further encouraged China to seek their own alternative approach to global standards.[3] We must learn from this experience, among many other lessons, about the strategic importance of maintaining open and fair international engagement for standards, metrology and trade.[4]

Question 2. The recent Merit Review Commission's report suggests revising NSF's merit review criterion from "broader impacts" to "societal benefits," which seems like a distinction without a difference. Both criteria can be interpreted expansively in ways that have nothing to do with scientific merit or outcomes. When demographic composition or social frameworks become decision factors separate from the scientific research product, merit review collapses into ideological favoritism, something we saw from grants awarded under the previous administration.

a. Given your former role as NIST Director and experience with the merit review process for making Federal awards, what specific operational safeguards and clear definitions are needed to prevent "societal benefits" criterion from being interpreted in ways that subordinate scientific merit to political goals?

Answer. Senator Cruz—thanks very much for your thoughtful question on the addition of societal beneﬁts criteria to the NSF merit review process. The American Physical Society (APS) has also commented in favor of the direction to address the equal importance of intellectual merit and societal impact in evaluating NSF proposals.[5] It is clear that more work needs to be done[6] in the quantitative and qualitative indicators of societal beneﬁts to ensure consistent interpretation of the criteria and to put these into practice appropriately in the merit review process.[7] The actions to follow must further connect science advances with society in meaningful and measurable ways, and I look forward to these next steps to ensure that scientiﬁc merit is never subordinated to political whims in the merit review process.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MARIA CANTWELL TO DR. WALTER COPAN

Supporting Manufacturing Extension Partnership Program

Question. Dr. Copan, as a former Director of the National Institute of Standards & Technology (NIST), you oversaw the Manufacturing Extension Partnership (MEP) and saw firsthand how it supports small and medium-sized manufacturers. Since April 2025, NIST has withheld or delayed congressionally appropriated funding, imposed new conditions on MEP centers, and reduced the Federal staff responsible for administering the program. That uncertainty has reportedly led to hiring freezes and layoffs at 90 percent of MEP centers. The Administration's Fiscal Year 2027 budget once again proposes eliminating MEP, and the current NIST Director declined to support it during their confirmation hearing.

Based on your experience leading NIST, do you support fully funding and executing the Manufacturing Extension Partnership program? What would weakening or eliminating MEP mean for small and medium-sized manufacturers trying to adopt advanced technologies and compete internationally?

Answer. Senator Cantwell, thank you for this important question and for your support for the Manufacturing Extension Partnership. The MEP has delivered substantial value to the Nation's small and medium-sized manufacturers since its founding in 1988. Fully funding and advancing the MEP mission is essential now because it gives small and medium-sized manufacturers practical access to the technologies, expertise, cybersecurity practices, workforce support, and supply-chain capabilities they need to compete. The MEP needs to continually improve and modernize its capabilities, technology delivery and services. Weakening or defunding

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[2] China's High-Tech Drive in 10 Charts: *https://www.csis.org/analysis/chinas-high-tech-drive-10-charts*

[3] U.S. drafts rule to allow Huawei and U.S. firms to work together on 5G standards: *https://www.reuters.com/article/technology/exclusive-us-drafts-rule-to-allow-huawei-and-us-firms-to-work-together-on-5-idUSKBN22K214/*

[4] United States Standards Strategy (USSS) 2025: *https://www.nist.gov/standardsgov/united-states-standards-strategy-released*

[5] *https://www.aps.org/about/news/2026/01/nsb-merit-review-report*

[6] *https://casrai.org/guides/nsf-broader-impacts-statement-review-criteria*

[7] *https://clarivate.com/academia-government/wp-content/uploads/sites/3/dlm_uploads/2026/04/Clarivate-Societal-IMpact-Framework-a-guide-to-responsible-research-impact-measurement.pdf*

MEP would undercut the very firms that form the backbone of the industrial base and slow the Nation's ability to scale advanced manufacturing at a time when the United States needs to rebuild manufacturing capacity and strengthen supply-chain resilience.

The MEP mission complements Manufacturing USA and its Institutes, and the SBIR/STTR investments that help technology businesses advance. In the future, MEP must also facilitate giving manufacturers even greater access to advanced manufacturing technologies and practices, to the NIST capabilities, to the Baldrige Performance Excellence Program, to other Federal laboratories and research institutes. Maximizing the synergies among these programs will be essential to strengthening U.S. economic competitiveness and resilience.

The U.S. needs a highly effective and fully funded MEP both today and for the future. It's reported that 80 percent of U.S. jobs created since 2025 have been in small- and medium-sized enterprises.[1] It is essential that the MEP continually improve its operational efficiencies—and it must adapt to the changing needs and advanced technology opportunities of the times. The MEP can continue to improve as a resource for business effectiveness, providing access to shared services, facilities and technology expertise. I am excited for the new NIST MEP Technology Accelerator Pilot Program announced in 2026 that is intended to speed the adoption and commercialization of advanced manufacturing technologies to enhance the competitiveness of the domestic industrial base. I encourage the use of such pilot programs, as they provide data and relevant experience that can define the future directions for MEP and validate its impacts for the Nation. Now is the time when the Nation urgently needs to build its advanced manufacturing capacity and resilient supply chains. As a nation, we have allowed China to overtake us in advanced manufacturing with trusted supply chains across multiple industries—and China has made no secret of its ambitions to continue to dominate global manufacturing, including those industries where the U.S. has had historic technology leadership.

China is making serious investments to achieve manufacturing leadership at scale. To compete effectively, the United States must recognize that scale matters when translating innovation into industrial capacity. China modeled its Manufacturing Innovation Centers after the Manufacturing USA program and made them central to its Made in China 2025 plans. It has planned for at least 40 centers, compared with 17 current Manufacturing USA institutes, and supports each center at a substantially higher level than the United States does. The consequences have been enormous. For example, when China launched its National Power Battery Innovation Center in 2016, that nation was not yet a battery leader. By making a $750 million five-year investment, building and staffing an associated pilot line, and convening dozens of rival Chinese companies for joint research, China leveraged an additional $3 billion in private-sector manufacturing investments. China followed the U.S. model, but at a much larger scale, and today it dominates the global battery market. By comparison, a typical Manufacturing USA institute must stretch a modest $70 million over five to seven years. This funding gap allows China's 33 current national innovation centers to move technologies from lab to megafactory at a speed that 17 under-capitalized U.S. institutes cannot match.

If the United States wants to lead again and secure its future in advanced manufacturing, Congress should take immediate action to consider doubling the Manufacturing USA network's footprint and at least tripling individual institute funding.

Defunding the MEP would be a huge strategic mistake. A substantial portion of the Nation's industrial economy is powered by small and medium-sized suppliers. They account for nearly nine in ten firms in key industrial sectors, which makes them critical to strengthening domestic supply chains[2]—which will also be advanced by innovative entrepreneurial ventures. The defense industrial base further benefits from the work of the MEP, in supporting the quality fabrication of needed products, aided by advances in AI, robotics and industrial automation, and the implementation of cybersecurity systems.

In summary, the United States should fully fund MEP and continue strengthening its renewed vision for national impact. NIST has demonstrated a commitment to improving MEP performance, including by responding to OIG findings. MEP can also help drive innovation through partnerships among NIST, Federal research institutions, and small and medium-sized enterprises. Its role in creating common platforms for access to new technologies, cybersecurity capabilities, and privacy-management practices is essential, particularly because many SMMs lack the capac-

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[1] *https://www.uschamber.com/small-business/how-small-businesses-are-fueling-u-s-job-growth*

[2] *Investing in America's Suppliers: The Importance of Small and Medium-Sized Businesses in America's Reindustrialization | Next Street Reports*

ity to develop and implement protocols that meet Department of Defense and other customer requirements on their own.

If the U.S. is really going to get serious about regaining world class advanced manufacturing capabilities and building our future manufacturing workforce, paying attention to our SMMs is essential.

Building a TechNATO

Question. I have long called for a "TechNATO," an alliance of the U.S. and other leading technology democracies to establish common rules of the road for critical technologies. That means agreeing on principles such as protecting intellectual property, preventing government back doors, developing trusted technical standards, and helping countries deploy technologies that meet those standards. As China promotes its own technologies and economic model around the world, the U.S. should work with allies to offer a credible democratic alternative.

Do you agree with the TechNATO idea? How could a TechNATO strengthen U.S. scientific and technological competitiveness and improve our ability to compete with China?

Answer. Senator Cantwell, I support the idea of establishing a TechNATO and would welcome the opportunity to learn more about your vision for such a partnership. The United States needs to rebuild its reputation and capacity for productive global partnerships and re-establish key alliances in science and technology. Pulling back from international research and innovation partnerships limits access to technology and weakens the talent pipelines that are essential to the next generation of global innovation leadership. The principles you outline are well aligned with the need for the United States to work with like-minded partners that share a common vision for innovation in democratic societies.

As I indicated in my testimony, China has learned from the rest of the world and uniquely has adapted how to build and sustain a world-class research, development, education and innovation engine. China is also increasingly a source of technologies from which the rest of the world can benefit. With China's ascendance, it is essential for the United States to strengthen and leverage its strategic partnerships with allies. The United States should redouble public and private investment and play the long game in research and innovation. It must be a consistent partner with global collaborators, maintain reliable and trustworthy relationships for mutual value, and share in research directions and investments. Working together on the front end of technologies enables closer collaboration in standards setting and implementation and helps build more resilient supply-chain partnerships. The United States can also leverage the investments of like-minded partners and have a stronger voice in developing a shared technology agenda.

On the topic of the long game for U.S. science and technology, I further recommend that this committee consider an extension of the normal term of service for leaders of the Nation's principal science agencies to a minimum of six-year terms to enable the maintenance of longer-term technology strategy as well as continuity of leadership roles. Our current "stop-start" process that is tied to political cycles creates leadership gaps for a number of our agencies, with innovation and national security risks for the United States. International partnerships through a "techNATO" could be better sustained through more stable relationships and demonstrated trustworthiness by the United States with "techNATO" allies in mutual commitment to research, technology advancement and innovation.

AI Standards and NIST

Question. Dr. Copan, as a former Director of NIST, you understand the agency's unique role in bringing together technical experts, industry, and government to develop measurement tools and voluntary standards for emerging technologies. For AI, we need guardrails that protect the public without slowing down innovation.

What makes NIST the right institution to develop AI standards, testing methods, and guardrails that protect the public, support innovation, and strengthen U.S. leadership in AI?

Answer. Senator Cantwell, NIST is the right institution for this work because it is trusted, exceptionally strong in measurements science and technology, and fundamentally non-regulatory. Developing measurements and standards for AI system performance is central to NIST's mission. NIST has already worked with OECD, research organizations, and industry globally to define responsible AI principles and to establish the NIST AI Risk Management Framework. I was encouraged by the creation of the AI Safety Institute and now the Center for AI Standards and Innovation (CAISI), which can provide the Nation with a focused resource to support innovation, evaluate AI capabilities, and measure AI system performance and risk.

NIST's National Cybersecurity Center of Excellence (NCCoE), for example, has a trusted relationship with industry in appropriately assessing and handling cybersecurity vulnerabilities and risks. Without such trusted, confidential relationships together with proven processes of managing cybersecurity threats, NIST and the NCCoE resource would not have the global impact that they enjoy. After all, NIST is the entity trusted worldwide to handle the selection and testing of post-quantum cryptographic algorithms and systems, as well as the development and advancement of the NIST Cybersecurity Framework that is adopted internationally.

I have been concerned that CAISI has so far been under-resourced for the needs of the United States. After all, if the U.S. is to remain the world's AI leader, the Nation's primary institute for advancing the field should have the consistent leadership with appropriate levels of expert staffing and metrology capacity to measure and lead for AI standards deployment, performance assessment, and development of risk management strategies.

Further, I do not believe that an institute like CAISI should play a regulatory role for the nation, but rather provide the underlying measurements, data and standards that are essential for appropriate systems implementation and decision making. An example is the development of the NIST cybersecurity standards that have been established through voluntary consensus processes and expert inputs. Such controls and standards may then be utilized in regulatory frameworks by agencies effectively staffed and equipped to utilize them for their mission space, as has the Department of Defense in the implementation of the NIST Special Publication SP 800–171 security controls required to protect Controlled Unclassified Information (CUI). The DOD CMMC (Cybersecurity Maturity Model Certification) program can then verify through audits that those security controls are implemented. Another example is the set of security standards in NIST SP 800–171A that are ultimately used in Federal Information Processing Standards (FIPS) to guide Federal agencies in transitioning computer systems to stronger cryptographic algorithms.

It would be a mistake to impose a regulatory role upon NIST, as this would change the dynamic of relationships between the agency and its stakeholders. It is essential for the United States to maintain an open measurements-driven standards process that enables innovation to flourish.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. TAMMY BALDWIN TO DR. WALTER COPAN

Question 1. As a former NIST Director, you're able to speak firsthand about the challenges presented when funding is inconsistent and goal posts are moving—and what the Federal government can accomplish when committed to scientific research, innovation, and competitiveness. The work coming out of the Wisconsin Biohealth Tech Hub is just one example of what can be done with consistent Federal investment.

- Dr. Copan, can you discuss the importance of reliable funding for science and research to spur American innovation, coordinate across the public and private sector, and compete with China in strategic areas?

Answer. Senator Baldwin, thank you for this important question. A stable and reliable research enterprise is essential for the Nation's productivity and competitiveness. Abrupt changes and frequent priority shifts harm research systems by slowing work in the Nation's highest-priority research areas. As I noted in my testimony, Federal funding reductions and uncertainties have decreased research data production, publications, intellectual property filings, and cut investable venture opportunities. The United States has also seen reductions in domestic and international talent pipelines and is experiencing a brain drain of experienced researchers to other nations, along with withdrawals and retirements from the U.S. STEM workforce.

Sudden changes in research funding allocations, directions and priorities risk stranding capital investments in research infrastructure, scattering specialized teams, halting project progress, discouraging industry collaboration, and disrupting the STEM talent pipeline by stalling the development of graduate students and postdoctoral researchers. In many cases, projects that had been previously approved through a Federal agency's merit review process but were then prematurely terminated had corporate partners who had made substantial commitments of resources and funding. All the planning and implementation efforts of these companies and their research partners ultimately were wasted for the U.S. economy—even if, months later, it was communicated that the projects may be reinstated. Across the U.S., we have experienced a decline in graduate enrollments in STEM fields, where qualified researchers are no longer able to continue their studies and research pursuits. Furthermore, the threat of sudden award terminations can discourage institu-

tions from pursuing high-stakes, long-term lines of research, diminishing or losing returns on taxpayer investments. Additionally, pauses or terminations in research programs result in the U.S. research enterprise becoming a less reliable partner for industry and international collaborators.

To achieve maximum strategic alignment without destabilizing the research ecosystem, the Federal government must utilize established collaborative frameworks, such as scientific advisory boards, to ground future priority shifts in objective, peer-validated data. Incorporating structural input from the research community and relying on expert advisory bodies, including the National Academies of Science, Engineering and Medicine, will help ensure Federal accountability while preserving the stable research environment necessary to advance American science, technology, and competitiveness. The National Science and Technology Council convened by OSTP can provide a functioning forum for interagency coordination and collaborative management toward the Nation's long-term priorities.

Question 2. The President's FY27 budget proposes to completely eliminate the Manufacturing Extension Partnership, a program that provides support to small and medium-sized manufacturers on a wide range of topics, including improving efficiency, building resilient supply chains, upgrading technology, and training workers. The Wisconsin center helps manufacturers identify opportunities to export their products, as well as navigate using AI.

- Dr. Copan, can you share how the Manufacturing Extension Partnership complements other Federal manufacturing initiatives like Manufacturing USA, and why the MEP centers are critical tools for American competitiveness?

Answer. Senator Baldwin—as I also indicate in my response to the question from Senator Cantwell, the Manufacturing Extension Partnership has delivered substantial value to the Nation's small and medium sized enterprises throughout the years since MEP's founding in 1988. The MEP mission complements the Manufacturing USA program and the work of its institutes, as well as the catalytic effects of the SBIR/STTR investments for technology business advancement for the Nation. In the future, the MEP can also provide even greater access to the advanced technologies and capabilities of NIST, as well as the Baldrige Performance Excellence Program and other Federal labs and research institutes. Maximizing the synergies of *all* these manufacturing programs will be essential for the Nation's economic competitiveness and resilience.

The U.S. needs a highly effective and fully funded MEP both today and for the future. It's reported that 80 percent of U.S. jobs created since 2025 have been in small- and medium-sized enterprises.[3] It is essential that the MEP continually improve its operational efficiencies—and it must adapt to the changing needs and advanced technology opportunities of the times. The MEP can continue to improve as a resource for business effectiveness, providing access to shared services, facilities and technology expertise. I am excited for the new NIST MEP Technology Accelerator Pilot Program announced in 2026 that is intended to speed the adoption and commercialization of advanced manufacturing technologies to enhance the competitiveness of the domestic industrial base. I encourage the use of such pilot programs, as they provide data and relevant experience that can define the future directions for MEP and validate its impacts for the Nation. Now is the time when the Nation urgently needs to build its advanced manufacturing capacity and resilient supply chains. As a nation, we have allowed China to overtake us in advanced manufacturing with trusted supply chains across multiple industries—and China has made no secret of its ambitions to continue to dominate global manufacturing, including those industries where the U.S. has had historic technology leadership.

China is making serious investments to achieve manufacturing leadership at scale. To compete effectively, the United States must recognize that scale matters when translating innovation into industrial capacity. China modeled its Manufacturing Innovation Centers after the Manufacturing USA program and made them central to its Made in China 2025 plans. It has planned for at least 40 centers, compared with 17 current Manufacturing USA institutes, and supports each center at a substantially higher level than the United States does. The consequences have been enormous. For example, when China launched its National Power Battery Innovation Center in 2016, it was not yet a battery leader. By making a $750 million five-year investment, building and staffing an associated pilot line, and convening dozens of rival Chinese companies for joint research, China leveraged an additional $3 billion in private-sector manufacturing investments. China followed the U.S. model, but at a much larger scale, and today it dominates the global battery market. By comparison, a typical Manufacturing USA institute must stretch a modest $70

[3] *https://www.uschamber.com/small-business/how-small-businesses-are-fueling-u-s-job-growth*

million over five to seven years. This funding gap allows China's 33 current national innovation centers to move technologies from lab to megafactory at a speed that 17 under-capitalized U.S. institutes cannot match.

If the United States wants to lead again and secure its future in advanced manufacturing, Congress should take immediate action to consider doubling the Manufacturing USA network's footprint and at least tripling individual institute funding.

Defunding the MEP would be a huge strategic mistake. A substantial portion of the Nation's industrial economy is powered by small and medium-sized manufacturers (SMMs). They account for nearly nine in ten firms in key industrial sectors, which makes them critical to strengthening domestic supply chains[4]—which will also be advanced by innovative entrepreneurial ventures. The defense industrial base further benefits from the work of the MEP, in supporting the quality fabrication of needed products, aided by advances in AI, robotics and industrial automation, and the implementation of cybersecurity systems. In addition, the MEP and Manufacturing USA programs and participating organizations provide important outreach and training to build the future of America's manufacturing workforce. An actual withdrawal of funding or the threats of funding withdrawal result in destabilizing the environment for the future of the U.S. manufacturing workforce and will discourage individuals from considering such manufacturing career paths.

I trust that Congress will fully fund MEP going forward with its renewed vision for impact for the Nation. NIST has demonstrated its commitment to continue to enhance the performance of the MEP, including its response to findings of the OIG.[5] It's also clear that MEP can be a resource for driving more innovation through the partnership between NIST, Federal research institutions and small-and medium-sized enterprises. I believe MEP's role in creating common platforms for access to new technologies as well as basic capabilities for cybersecurity and privacy management are essential for the future of the country, as many SMMs do not have the individual capacity to develop and implement the cybersecurity and privacy protocols that meet the requirements of the Department of Defense and other customers.

If the U.S. is really going to get serious about regaining world class advanced manufacturing capabilities, paying attention to our SMMs and the future of our manufacturing workforce is essential.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. JOHN HICKENLOOPER TO DR. WALTER COPAN

Validation and Evaluation for Trustworthy Artificial Intelligence (VET AI) Act

Senator Capito and I have been working on a bipartisan bill called the Validation and Evaluation for Trustworthy Artificial Intelligence Act also known as the VET AI act.

This legislation would direct NIST to work with Federal agencies and stakeholders to develop detailed guidelines, and recommendations for third-party evaluators to work with AI companies to provide robust independent external assurance and verification of how their AI systems are developed and tested.

Question 1. Dr. Copan, how do voluntary consensus frameworks (like those in the VET AI Act) empower businesses to safely adopt and deploy AI?

Question 2. Dr. Copan, why is independent evaluation critical for building public trust and protecting consumers without creating bureaucracy for small and large businesses?Answer.

Science and Math Teachers

Currently, this country faces a science and engineering workforce shortage. It is *projected* that by 2030, the U.S. will face a shortfall of 1.4 million workers to fill these roles.

Within the next decade, 80 percent of jobs will require science, technology, engineering, and mathematics skills.

But it's not just the workers designing the Nation's electricity grid or developing new vaccines, it's also the educators training critical thinkers, increasing science literacy, and inspiring students to pursue these career paths.

Across the country there is a shortage of math and science teachers. This is true in all states and across urban, suburban, and rural areas.

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[4] *Investing in America's Suppliers: The Importance of Small and Medium-Sized Businesses in America's Reindustrialization | Next Street Reports*

[5] *OIG's Evaluation of MEP's Economic Impact Reporting Process Also Identified Instances of Noncompliance at Centers, Led to NIST Action | Oversight.gov*

Question 3. Dr. Copan, how do we encourage more students to pursue paths in STEM teaching and education, so that we can cultivate the next generation of innovators?

Answer. Senator Hickenlooper, thank you for participating in the hearing and for these thoughtful comments and questions. The following responses address your questions on voluntary AI frameworks, independent evaluation, and STEM education in turn.

Question 1. Dr. Copan, how do voluntary consensus frameworks (like those in the VET AI Act) empower businesses to safely adopt and deploy AI?

Answer. Senator Hickenlooper, thank you for your leadership in advancing important legislation such as the VET AI Act. I believe this type of legislation would be an important step forward for the Nation in ensuring the appropriate development and implementation of voluntary consensus AI standards with a central role for NIST. The United States has long adhered to the principles of an industry-led voluntary consensus process for standards development in which the Federal government is a partner in standards development and implementation, as summarized in OMB Circular A–119, and in the National Standards Strategy, most recently issued in January 2026.[6] NIST has had a lead role for the Nation in convening AI standardization efforts and coordination with standards bodies globally, and is a trusted expert collaborator in supporting innovation and industrial competitiveness.

Question 2. Dr. Copan, why is independent evaluation critical for building public trust and protecting consumers without creating bureaucracy for small and large businesses?

Answer. A trusted independent evaluation and assessment process outside a governmental regulatory regime can give confidence to industry, government, academia, consumers, and the public. The strength of a voluntary consensus process is that expert corporate and organizational engagement creates buy-in around measurements and standards that are relevant to trust and performance assessment for rapidly developing AI applications. Certified third-party evaluation, conducted according to agreed criteria and standards, allows companies large and small to have their systems validated objectively and to confirm the performance and safety claims of technology innovators and implementers.

Question 3. Dr. Copan, how do we encourage more students to pursue paths in STEM teaching and education, so that we can cultivate the next generation of innovators?

Answer. Senator Hickenlooper, Thank you. This is a critically important question for our country to address. I also address related issues in my response to Senator Blunt Rochester's question. I was very pleased to see the Federation of American Scientists working on these issues, and they developed a series of actionable recommendations in their report "Ensuring the Next Generation of STEM Talent through K–12 Research Programming".[7]

A multi-pronged approach is required, together with an unwavering, long-term commitment by the Nation to build the STEM talent base we need for durable success. The most consistent commentary I hear from any U.S. employer is their need for qualified workers.

A comprehensive program for STEM education and talent development in the U.S. should include strategic Federal funding, state level coordination and support, immigration recruitment and reform for highly skilled talent, regional technology hubs, incentive programs for industry apprenticeships, support for focused outreach by STEM professionals at all levels, communications and marketing campaigns, and early childhood and K–14 programs for STEM experience and literacy.

A stable and more predictable research and funding environment for our universities and research institutions is necessary to be able to maintain continuity and international partnerships, as well as to attract and retain talent to critical STEM fields from domestic pipelines and the brightest and best from around the world. The current environment of funding uncertainty has resulted in critical losses of STEM researchers and educators across the Nation's universities.[8]

Cuts to Federal research funding over the past 18 months (2025–6) have created an environment of discontinuity for STEM, resulting in reductions of graduate enrollments in STEM fields for 2026–2027 of 30–50 percent observed to date. In addi-

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[6] *https://www.nist.gov/standardsgov/united-states-standards-strategy-released*

[7] *https://fas.org/publication/ensuring-the-next-generation-of-stem-talent-through-k-12-research-programming/*

[8] America's Scientific Brain Drain Is No Longer Hypothetical: *https://www.realclearscience.com/articles/2026/07/14/americas_scientific_brain_drain_is_no_longer_hypothetical_1194182.html*

tion, the Nation has experienced a substantial slowdown in intellectual property filings from universities and research institutes over the past year. This further signals a potential decrease in U.S. innovation outcomes from licensing, commercialization and new tech startup businesses.

At the major scientific conferences held in the U.S. during 2025–6, there was a notable absence of exhibitors and participants from U.S. universities and Federal research organizations—who normally use these venues for attracting partners and recruiting future employees, students and postdoctoral research fellows. Not only was this a visible indicator of a reduction in U.S. STEM outreach, but the gap was filled by research organizations from other nations, most notably China, as well as Japan and other Asian Nations, Europe, Canada, and South America. They were here in the U.S. actively recruiting American STEM talent. These dynamics are also likely to reduce the pool of available talent to be attracted to U.S. STEM teaching and higher education roles.

Teachers, professors, researchers and guidance counselors play critically important roles in encouraging students and families, supported by data and realistic forecasts of future STEM jobs. Many teachers are inspired by those who taught and mentored them and have come to see STEM education as both a mission and a calling. The nation has significant work to do to build this educational capacity at every level. STEM teaching must become a more attractive career path, and the Federal government can make important contributions toward that goal. Students need to be able to see themselves succeeding in industry-relevant STEM roles through hands-on experiences in laboratories, field work, robotics clubs, summer science camps, and regular engagement opportunities with STEM practitioners from industry and organizations of all types. Those same opportunities can also attract the next generation of STEM teachers and educators. Communications and marketing campaigns in partnership with STEM industries can help get the word out about the need for STEM educators and the increasingly attractive opportunities available.

- Federal funding will be essential to help build out key infrastructure, such as domestic semiconductor and quantum device fabrication facilities and regional innovation hubs. Teachers and students need to be able to see and communicate such STEM job opportunities that are current and emerging.
- School lab facilities need to be modernized, and Federal grants may be directed specifically toward upgrading public school science labs with modern engineering and computer science equipment.
- Financial support is needed for the institutional costs of providing STEM education, as a partnership between the Federal government and states. STEM students, including master's and doctoral students, need to be able to manage the financial burdens of pursuing advanced technical degrees, and ultimately to be attracted to the teaching professions.
- Students also need to see a financially attractive future in pursuing a career in STEM education and research. Federal matching funds may be provided for states that offer attractive starting salaries or bonuses for STEM teachers.
- States can be incentivized to make STEM pathways and computer science mandatory graduation requirements for all high school students.
- Ongoing training and professional development is essential to keeping teachers current, effective and aligned with industry standards and needs, while also helping to attract top STEM talent to the teaching and research professions. The Federal government can invest in and subsidize development and implementation of specialized STEM teacher professional development programs.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. LISA BLUNT ROCHESTER TO DR. WALTER COPAN

Question 1. Dr. Copan, the "Colorado School of Mines" recently launched the Nation's first bachelor's degree in quantum systems engineering.

a. As you worked with industry to develop the quantum systems engineering major, what did employers say they need most from the next generation of quantum workers?

Answer. The development and implementation of the first U.S. standalone undergraduate B.S. program and curriculum in Quantum Systems Engineering at Colorado School of Mines was substantially shaped by industry feedback. The university is ranked in the top engineering programs in the nation, with a heritage of pragmatic research and strong industry engagement that goes back to the university's

founding in 1874. The design of the new bachelor's program was a natural extension of the Mines graduate interdisciplinary program offerings in quantum science and engineering, in response to a clear need from the dynamic and rapidly growing quantum industry sectors. Mines faculty and collaborators published a roadmap for the development of a quantum undergraduate program several years ago[9] that was significantly informed by industry needs—and also built upon relationships through the NIST-sponsored Quantum Economic Development Consortium (QED–C). Colorado has a high concentration of corporate partners addressing the full quantum technologies stack, with over 3,000 people working in the quantum industry.[10] The presence of NIST in Boulder is a national resource that provides industry, researcher and student opportunities for quantum collaborations, facilities access, and entrepreneurial development.

Elevate Quantum was established as the first quantum hub nationally with support from Economic Development Administration funding and is now aiming for its second phase of development. It is estimated that over 50 percent of the future quantum workforce will not require an advanced degree. Industry feedback made clear that many opportunities exist at the bachelor's level for engineers with interdisciplinary, system-level training who are quantum savvy, strong team players, effective communicators, and experienced and confident in hands-on work. These roles may involve integrating lasers, cryogenics, hardware components, mechanical systems, and software to help scale the quantum sector. The curriculum reflects those needs by blending physics, electrical engineering, computer science, mechanical engineering and engineering design, and requiring a year-long capstone program with industry-sponsored projects, cross-disciplinary teams, business partners, and mentors.

Question 2. The United States is making significant investments in emerging technologies, but those investments will only succeed if we have a strong pipeline of scientists, engineers, technicians, and skilled workers to support them.

a. Beyond increasing research funding, what are the most important actions Congress can take to strengthen America's quantum and broader STEM workforce over the next decade?

Answer. Senator, thank you for this key question for our country to address, and I will build on my response to Senator Hickenlooper's related question. I was very pleased to see the Federation of American Scientists working on these issues, and they developed a series of actionable recommendations in their report "Ensuring the Next Generation of STEM Talent through K–12 Research Programming".[11]

A multi-pronged approach is required, together with an unwavering, long-term commitment by the Nation to build the STEM talent base we need for durable success. The most consistent commentary I hear from any U.S. employer is their need for qualified workers.

A comprehensive U.S. program for STEM education and talent development should include strategic Federal funding, state-level coordination, highly skilled immigration recruitment and reform, regional technology hubs, industry apprenticeship incentives, outreach by STEM professionals, communications and marketing campaigns, and early-childhood through K–14 programs that build STEM experience and literacy.

When Federal programs demonstrate real return on investment, we need the discipline to double down on what works. The EDA Tech Hubs program is a prime example: initial Federal investments have already proven they can catalyze massive regional momentum, leveraging tens of millions in baseline grant funding into hundreds of millions in state and private ecosystem capital.

Building world-class technology hubs takes sustained time, focus, and resources. As Federal leaders consider future funding rounds, we must ensure high-performing hubs receive consistent, strategic support rather than spreading resources so thinly that none can reach critical mass. Diluting funding risks undermining the momentum of our most promising regional hubs just as they are reaching scale.

A stable and more predictable research and funding environment for our universities and research institutions is necessary to be able to maintain continuity and international partnerships, as well as to attract and retain talent to critical STEM fields from domestic pipelines and the brightest and best from around the world.

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[9] *https://ieeexplore.ieee.org/document/9705217*

[10] *https://oedit.colorado.gov/blog-post/in-the-spotlight-colorados-leading-quantum-ecosystem*

[11] *https://fas.org/publication/ensuring-the-next-generation-of-stem-talent-through-k-12-research-programming/*

The current environment of funding uncertainty has resulted in critical losses of STEM researchers and educators.[12]

Cuts to Federal research funding over the past 18 months (2025–6) have created an environment of discontinuity for STEM, resulting in reductions of graduate enrollments in STEM fields for 2026–2027 of 30–50 percent observed to date. In addition, the Nation has experienced a substantial slowdown in intellectual property filings from universities and research institutes over the past year. This further signals a potential decrease in U.S. innovation outcomes from licensing, commercialization and new tech startup businesses.

At the major scientific conferences held in the U.S. during 2025–6, there was a notable absence of exhibitors and participants from U.S. universities and Federal research organizations—who normally use these venues for attracting partners and recruiting future employees, students and postdoctoral research fellows. Not only was this a visible indicator of a reduction in U.S. STEM outreach, but the gap was filled by research organizations from other nations, notably China, Japan and other Asian Nations, Europe, Canada, and South America, actively recruiting U.S. STEM students and researchers. These dynamics are also likely to reduce the pool of available talent in the U.S. to be attracted to the STEM workforce.

Teachers, professors, researchers and guidance counselors have critically important roles to play in providing encouragement and meaningful information to students and their families, backed by data and realistic forecasts of the industry-relevant STEM jobs of the future. Students' engagement in STEM can be reinforced through hands-on experiences in laboratories, field work, robotics clubs, summer science camps and regular engagement opportunities with STEM practitioners from industry and organizations of all types. Communications and marketing campaigns in partnership with STEM industries can help get the word out about the attractive opportunities available and emerging in STEM fields.

- Federal funding will be essential to help build out key infrastructure, such as domestic semiconductor and quantum device fabrication facilities and regional innovation hubs. Teachers and students need to be able to see and communicate the STEM job opportunities that are current and emerging.
- School lab facilities need to be modernized, and Federal grants may be directed specifically toward upgrading public school science labs with modern engineering and computer science equipment.
- Financial support is needed for the institutional costs of providing STEM education, as a partnership between the Federal government and states. STEM students, including master's and doctoral students, need to be able to manage the financial burdens of pursuing advanced technical degrees.
- States can be incentivized to make STEM pathways and computer science mandatory graduation requirements for all high school students.
- Ongoing training and professional development is essential to keeping teachers current and effective, and the availability of such programs can help attract STEM talent to the teaching and research professions. The Federal government can invest in and subsidize development and implementation of specialized STEM professional development programs.
- America must rebuild itself as a magnet for the world's best talent. One proposal is to offer permanent residency, subject to appropriate vetting, to international students who earn STEM master's or doctoral degrees from accredited U.S. universities.
- We can lengthen the Optional Practical Training (OPT) period for qualified and vetted international graduates to work in U.S. technology industries post-graduation.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. TED CRUZ TO DR. DREW ENDY

Question 1. The National Security Commission on Emerging Biotechnology identified biotechnology as a transformative technology for national economic resilience in the next decade. Your work on Large Language Laboratories offers a compelling model.

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[12] America's Scientific Brain Drain Is No Longer Hypothetical: *https://www.realclearscience.com/articles/2026/07/14/americas_scientific_brain_drain_is_no_longer_hypothetical_1194182.html*

a. What would Large Language Laboratories contribute to American biotechnology leadership?

Answer. Models need data. No data, no model. Bad data, bad model. Historically, the United States has led the world in generating biological data at scale, but only for a few types of data. The best historical examples are DNA sequence data and protein structure data. The former gave rise to the Human Genome Project, post-genomic medicine, and generative biology for nucleic acids. The latter gave rise to protein structure and function models, most recently those like AlphaFold, which are unlocking a revolution in everything from drug development to bottom-up molecular self-assembly of advanced materials.

Note that the scaling of data generation for both DNA sequence and protein structure data was led by public investments, initially through the Department of Energy. Biology today is ripe for collecting data at scale for several additional types of critical biological molecules and state variables. Whichever nation leads the collection of such data will have the best models for biology going forward. Such foundational leadership is extraordinarily high leverage and will impact everything from manufacturing resilience to energy dominance and biosecurity.

RNA structure data and whole-cell molecular structure data are examples of two classes of data that the United States should invest in scaling the collection of right now. In addition, for DNA sequence data, we should sequence all the organisms to be found in the United States, as recommended by the NSCEB.

Most importantly, we should no longer simply create laboratories that collect and annotate data passively. Large Language Laboratories (LLL) must be designed and resourced to create a loop between reading (*i.e.,* data generation or collection) and writing (*i.e.,* creating physical instances that test the correctness of our models and conclusions). For example, an LLL for microbial genomics would sequence a microbe's DNA, use AI algorithms and other methods to annotate the sequence, resynthesize the genome from scratch to only encode the so-annotated functions, and test the resulting synthetic genome to see if it still works; differences between expected and observed behavior reveal gaps in our knowledge and accelerate improvement of our models.

Restated, LLLs must create a loop in which observation and testing go together at scale, with the resulting models in the middle. Only by doing this will the United States have the world-leading models for biology. LLLs would provide the missing experimental capacity. LLLs would combine advanced computing with automated prototyping, high-throughput testing, and standardized measurement to generate reliable, AI-ready biological data at scale. LLLs would make it possible to train models that better predict how biological systems behave, generate useful new sequences and designs, and reduce the time and experimentation needed to get increasingly complex biotechnologies to work. One outcome (*i.e.,* victory condition) is to move bioengineering from repeated tinkering to a mature and robust field of technology whose workflows can be best described as "design, build, work" in place of today's "design, build, test, learn."

b. Is this the type of infrastructure that would allow the U.S. to maintain and expand its advantage in biotechnology?

Answer. Yes. Whichever nation best connects biological models to physical experimentation at scale will improve its models, tools, and workflows fastest. The resulting advantages will compound across all of biotechnology.

Having just returned from a trip to China, I can report that the United States does not now have experimental infrastructure comparable to the national-scale facilities operating in Shenzhen and elsewhere in China. Without LLLs the United States will be unable to convert American strengths in artificial intelligence, computing, and basic science into sustained biotechnology leadership. The Department of Energy (DOE) is likely the best department to quickly create and operate LLLs for biology at scale. The National Institute of Standards and Technology (NIST) is the best place to advance the measurement science and standards needed to scale the reproducibility, reliability, and usefulness of such capacities. DOE plus NIST advancing the next generation of public-benefit biotechnology platforms together offers a massive synergy and strategic opportunity for the United States.

Question 2. The Commission also identified significant security risks. Biotechnology coupled with AI-enabled design tools offers tremendous opportunity but also vulnerability. Biological systems are difficult to reproduce, hard to verify, and the same tools that design beneficial organisms can be misused.

a. How do we maintain an open scientific culture and international collaboration in biotechnology while also ensuring research integrity and preventing dual-use technology from being weaponized or stolen?

Answer. China's wager is that a watched people will remain productive and innovative. Our counter-wager is that free people discover and innovate faster. Restated, a free and open (and sometimes unruly) culture of science is at the core of American science and is to our advantage.

Thus, we should preserve openness and a welcoming culture of science as the default while protecting a carefully bounded set of capabilities, data, and experiments whose misuse could create significant harm. Most foundational biotechnology research should remain open and internationally collaborative. But we must change how we govern a few domains of research.

Specifically, we must acknowledge and confront that building viruses from scratch is now routine. The issues arising are actually less to do with AI and more to do with the 1000-fold improvement in building viral genomes over the last two decades. We (the U.S. and others) have failed to adapt our governance approaches to account for this "new" world.

What to do? Research with a few pandemic potential pathogens (*e.g.,* human and human-adjacent influenza; human and human-adjacent coronaviruses) should be governed like we govern research with smallpox—illegal at a Federal level except for well-supported work in specific laboratories that are inspected and governed on a multilateral basis.

The virology research community will correctly complain that such a policy change would impact how their work is governed. True. But the tradeoff is a modest amount of scientific oversight for a massive amount of public and geopolitical trust along with a deescalation of nation-state bioweaponization rhetoric on a global scale. Moreover, well-resourced and well-governed research and oversight can move faster and lead to better research and public health and biodefense outcomes.

Research integrity also requires better measurement, standards, and traceability. Stronger biometrology at NIST and common standards for AI-ready biological data would make science both more useful and more trustworthy.

Finally, we must also prepare for a future in which biotechnology and AI both continue to advance and the resulting capacities continue to proliferate. We must act to secure biology really, over the longer term. Doing so is a solvable problem that only requires choosing to secure biology as we do other domains (*e.g.,* cyber, nuclear). Please see our 2025 report: *https://www.hoover.org/research/biosecurity-really-strategy-victory.*

Question 3. Having trained thousands of students in synthetic biology through the establishment of undergraduate bioengineering majors at both MIT and Stanford and founding of the iGEM competition, you understand what it takes to build a deep, world-class talent pipeline.

a. Beyond counting PhDs, what metrics should Congress use to assess whether American universities are actually training the right mix of scientists, engineers, and technicians needed for the specific technologies most critical to national competitiveness?

Answer. Measures of competitiveness in counts of people, patents, and publications are distant proxies for reality. What does biotechnology victory look like? Define the "end zone(s)" first. Then measure progress towards the end zone. I offered 12 examples of such metrics in my written testimony. The United States government should make these metrics national priorities.

As a follow-on to your specific question here let me expand on one of the 12—what percentage of people in the United States can read and write DNA? How does our (the United States') practical and applied bio-literacy compare to other countries? The reason these questions are better is that the answer to your question is not knowable. Even a centrally planned economy would get the answer wrong. Instead we have to create or renew an educational and workforce training system that gives every American options to learn about what is most needed and to find or create economic opportunities locally as the world changes. To make this possible the United States should do for science and technology education what the public library system did for literacy over a century ago. We have written more about this here: *https://issues.org/labraries-chappell-quiroz-kong-endy/*

b. Is the U.S. graduating enough people with both theoretical knowledge and hands-on manufacturing and translation experience?

Answer. No. But the way to fix it is not to prescribe that more such people must be trained and graduated. Rather, the fix is to create national priorities with specific goals (*e.g.,* see (9) from my written—what fraction of what the United States needs or consumes can be grown in the United States?), and then answer such questions and declare publicly that, in this example, the percentage should increase by some amount over a certain period of time. Restated, create the incentives and let

our free market system—which is in turn supported by our educational system—respond.

RESPONSE TO WRITTEN QUESTION SUBMITTED BY HON. MARIA CANTWELL TO DR. DREW ENDY

CHIPS and Science for Biotech

Question. In 2022, Congress passed the CHIPS and Science Act because the United States had fallen behind in domestic semiconductor manufacturing and needed a coordinated strategy that linked research, workforce development, regional innovation, supply chains, and production. Biotechnology may be approaching a similar point. The United States remains a leader in biotechnology research, but China is rapidly expanding its biotechnology industry and now conducts more clinical trials than the United States.

What would a CHIPS and Science-style strategy for biotechnology need to include for the United States to remain competitive with China?

Answer. The United States has not yet lost bio-manufacturing leadership to China but we are at risk of losing in real time. The United States does support "pilot" scale biomanufacturing. Up to 10x more support for pilot scale translation is needed. Where the United States is most vulnerable, however, is with full-scale biomanufacturing—industrial facilities that leverage biotechnology processes to supply the markets at full economic scale.

Having just returned from China I estimate that China will invest up to $500 billion USD in accelerating biomanufacturing over the next few years. This is not an official number, rather a sense gathered from many conversations. Having also carefully reviewed unpublished research from Australia I expect that China is already building more new biomanufacturing capacity than the rest of the world combined.

Thus, it would be easy to recommend that the United States should match such spending directly from the public treasure. Maybe. The return on investment to our domestic economy is likely worth it. Another, complementary approach would be to create tax incentives that support capital allocators in the private markets to make good decisions about how to invest in onshore biomanufacturing capabilities soon enough to matter. Restated, what can the Congress do to help the private sector efficiently allocate several trillion dollars to onshore biomanufacturing by or before 2040? Answering the question this way may be a better path forward. Please see "Bio-Bonds for a Bio-Belt" as one elaboration on this idea: *https://setr.stanford.edu/news/how-bio-bonds-can-help-build-world-class-biomanufacturing-infrastructure-across-america*

Where a CHIPS and Science-style strategy for biotechnology absolutely needs public support is in the foundational science and tools underlying biotechnology. The DOE should be tasked and funded at a scale that effectively creates the equivalent of two-new national laboratories worth of biotechnology effort. Immediate new efforts within the DOE portfolio should focus on "Large Language Laboratories" (above) and a National Biotechnology Accelerator that focuses on new tools and practices that accelerate and improve biotechnology workflows.

Commerce should be tasked and funded at scale so that NIST creates a Bio-Measurement Laboratory (BML), doing for biology what NIST's Physical Measurement Laboratory (PML) and Materials Measurement Laboratory (MML) deliver for physics and chemistry, respectively.

Finally, Congress must establish sustained coordination and accountability across administrations. Progress should be measured through real capabilities: who is best at building DNA, how quickly can new products be prototyped and brought to market, who operates the most efficient biomanufacturing processes, what fraction of what America needs can be grown domestically, and how much of the global bioeconomy is enabled by U.S. biotechnology. A successful strategy would ensure that discoveries made here can be measured, translated, manufactured, and secured here. China is implementing 5-, 10-, 20-, and 30-year plans for biotechnology. We are throwing out our plans every 18 months or simply doing nothing with the plans we have.

RESPONSE TO WRITTEN QUESTION SUBMITTED BY HON. LISA BLUNT ROCHESTER TO DR. DREW ENDY

Question 1. The United States is making significant investments in emerging technologies, but those investments will only succeed if we have a strong pipeline of scientists, engineers, technicians, and skilled workers to support them.

a. Beyond increasing research funding, what are the most important actions Congress can take to strengthen America's quantum and broader STEM workforce over the next decade?

Answer. I am not a quantum expert, so I would defer to those working directly in that field on its specific technical and workforce needs. But the broader workforce challenge is familiar. We should stop treating advanced science and engineering as pathways available only to people who already know how to find them. The United States once built public libraries so that anyone could learn. We should apply that same logic to the frontiers of science and technology by creating public "labraries" where people can encounter modern tools, develop practical skills, and discover opportunities in emerging fields.

Congress should also expand access to real instruments and shared technical facilities. High schools, community colleges, universities, national laboratories, and employers should create more opportunities for students and workers to use advanced equipment, participate in apprenticeships and internships, and earn credentials that lead directly into technical careers. Not every essential role requires a Ph.D., but every learner needs a visible entry point and a credible path forward. The BioBuilder Educational Foundation is one example of how to get this right.

Finally, we should measure whether people can actually do the work. How long do strategically important positions remain unfilled? How many people have practical experience operating advanced equipment and troubleshooting complex systems? How much additional training do employers need to provide before new hires can contribute? Whichever nation gives the most people the option to find and make opportunities at the frontiers of science and technology will have a durable advantage.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. TED CRUZ TO DR. ROBERT ATKINSON

Question 1. Congress currently measures American scientific strength by counting R&D dollars and publications. However, we need metrics that tell us whether we are winning in competition with China.

a. If Congress wants to know whether federally funded research is strengthening U.S. competitiveness, what should agencies be required to measure separately from policy-compliance goals?

Answer. There are a number of metrics that can help with this.

First, recipients of Federal funds (*e.g.,* Federal labs and universities) should be required to report the amount of funding they receive from industry. Labs and universities that do not perform well on this metric should see modest funding cuts, with the savings going to labs and universities that better engage with industry.

Second, all research awards should be coded as to whether they are conducting research in one of the ten critical technology areas identified in the Chips and Science Act.

Third, Federal labs have a series of performance metrics, but the indicator for technology commercialization counts for very little in their evaluation. This indicator should have significantly more weight.

Finally, Under the Bayh-Dole Act (35 U.S.C. § 200–212), any patent resulting from federally funded research must include a "government interests" or "government rights" clause. A Federal agency (perhaps Department of Commerce) should be responsible for tracking these every year and ranking labs and universities in patents per million dollars of Federal funding and ranks federal agencies on their "patent productivity."

b. How should Congress distinguish scientific outcomes, such as technical capability, standards influence, workforce depth, and technology diffusion, from metrics that do not measure competitiveness?

Answer. New research shows that at least half the benefits of federally funded science "spillover" to foreign nations. So simply counting awards and peer reviewed articles is not a good indicator of effect on national competitiveness.

For standards, there are many "standard essential patents." Again, Commerce should analyze these every year and identify government-supported research that helped generate such a patent.

Workforce depth, while a useful indicator, is very difficult to measure. One measure might assess universities based on the amount of Federal funding as a share of total STEM graduates.

especially those most related to Chinese competitiveness (*e.g.,* engineering, biosciences, chemistry, CS and math)

Technology diffusion is another indicator that is difficult to measure, in part because companies that use technologies can get them from anywhere.

I believe that key metrics should be mostly related to the development of new products, including the creation of startup companies that stem from federally funded research.

Overall, Commerce, perhaps in conjunction with NSF, should produce an annual ranking of federal labs and research universities in terms of the most and least significant contributions to the U.S. China techno-economic competition, using the indicators described above. These scores should be controlled for institution size.

Ideally, the rankings would have an impact on Federal funding, but even if they don't, they should produce some behavioral changes, as many labs and universities would seek to boost their rankings.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. JOHN HICKENLOOPER TO DR. ROBERT ATKINSON

International Scientific Collaboration

In your testimony, you raised the need for joint research initiatives with allies.

Established entities such as the Defense Innovation Accelerator for North America, DIANA, engage the international academic community to collaborate on hard technological problems related to our collective defense.

However, this culture of scientific exchange is in jeopardy. In February, researchers at the National Institute of Standards & Technology were told that foreign nationals with established careers at the lab, including those from the European Union, would be required to leave their roles.

This policy was walked back following Congressional pushback but is just one example of how this administration is undermining international science collaborations with allies.

Question 1. Dr. Atkinson, how can we better support international collaboration—both existing efforts like DIANA and new ones—to leverage the best-in-class research and advance the American scientific enterprise?

DIANA is indeed a model that should be expanded to other areas.

Regarding foreign nationals working in the Federal research enterprise, ensuring appropriate scrutiny for Chinese and other nationalities from U.S. adversaries makes eminent sense. Blocking allied researchers does not.

OSTP should take the lead in identifying barriers to greater international S&T collaboration with allies. This should include fast-track visas and streamlined J–1/H–1B treatment for STEM researchers and grad students from allied countries, with reciprocal arrangements so U.S. researchers get equivalent access.

In addition, Congress should make sure that Federal grant-making agencies (NSF, DOE, NIH) have clear statutory authority to co-fund research with foreign counterpart agencies as a matter of course. Currently it happens by happenstance, with individual project-by-project MOUs.

Standing joint-funding authority and pre-negotiated IP/publication frameworks with a short list of trusted allies (Five Eyes plus Japan, South Korea, key EU states) would let co-funded projects launch in months instead of requiring new negotiated terms each time. Of course, any partnerships with other nations should be more or less reciprocal where U.S. researchers and firms receive similar level of benefits as the foreign country researchers and firms.

In addition, the CFIUS/CUI/export-control regime needs to "whitelist" allied nations so that cooperative efforts are more easily streamlined.

Another key area is coordinating allied participation in international standards bodies (ITU, ISO, IEEE working groups) so the U.S. and allies aren't showing up separately and getting outmaneuvered by coordinated Chinese delegations in technical standards votes. While at its core the standers process should be industry-led and voluntary, there is a gap in coordination. NIST and relevant foreign standards agencies should help fill that gap.

DOE should formalize allied-researcher access to DOE national lab user facilities (light sources, supercomputing allocations, fabs) on the same reciprocal-access model as some existing bilateral science agreements, rather than case-by-case foreign national access review that can take months.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. LISA BLUNT ROCHESTER TO
DR. ROBERT ATKINSON

Question 1. Dr. Atkinson, Congress has invested heavily in strengthening semiconductor supply chains after recognizing the risks of relying on foreign production.

a. As quantum technologies mature, what lessons should we apply now to ensure the United States builds secure and resilient quantum supply chains before similar vulnerabilities emerge?

Answer. The Federal government was asleep at the switch when it came to tracking supply-chain vulnerabilities. This is largely because Federal policy makers had adopted the globalist view that the entire world was evolving into a single integrated market governed by democracies.

Now they know better. So as a critical technology like quantum emerges, we cannot be left vulnerable again. To date many of the key vulnerabilities relate to Chinese rare earths (a vulnerability that was preventable with the introduction of a price floor on Chinese rare earth imports). As such, efforts to reduce dependencies on Chinese rare earths need to be accelerated.

At the same time, a Federal agency, ideally the Department of Commerce, should convene major quantum players in the United States (researchers and companies) to assess other supply chain vulnerabilities and risks (*e.g.,* an allied supplier is in a weak competitive position) and craft a strategy to address these. This will most likely take the form of at least a phased in ban on key Chinese inputs, coupled with support for U.S. production of these components.

Question 2. The United States is making significant investments in emerging technologies, but those investments will only succeed if we have a strong pipeline of scientists, engineers, technicians, and skilled workers to support them.

a. Beyond increasing research funding, what are the most important actions Congress can take to strengthen America's quantum and broader STEM workforce over the next decade?

Answer. ITIF has written a report on this issue titled "Mobilizing for Techno-Economic War, Part 4: Transforming Education and Workforce Policy." The key recommendation is to embrace more fundamental reforms. This issue has been discussed since the 1980s and very little has been accomplished. Simply encouraging kids to like science has not worked. We proposed a number of steps:

Congress should increase funding for the Carl D. Perkins Career and Technical Education Act that provides formula grants to states. And states should be able to apply for matching grants to be used to expand technical education in high schools, including engineering courses (*e.g.,* robotics) and maker spaces.

Land grant universities have lost their way and need to go back to focusing on "agricultural and mechanical arts." As such, Congress should pass a third Morrill Act to incentivize state land grant universities to return to their original mission, including cutting non-science programs, and building build world-class, industry-grade labs to enable applied research and technical training for students.

We need more universities focused on particular industries such the SUNY Maritime College, Kettering University (for automotive engineering) and the Colorado School of Mines. To build on these, Congress should appropriate funds to the Department of Education to establish a competition to establish up to 10 industry-or technology-focused universities.

Finally, it's not enough to just fund R&D in critical and emerging technology areas. We need to also fund curriculum development. This is what China is doing. In 2025, top universities, such as Tsinghua University, Peking University, and Shanghai Jiao Tong University, added 150 undergraduate places in emerging engineering fields such as AI, integrated circuits, and new energy. These specializations serve national strategy and align with emerging industries.

Congress should ensure that NSF has adequate funding to establish an annual funding program for research universities (including land grant colleges) to establish new science and technology curricula in areas of national importance.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. TED CRUZ TO
DR. JULIA PHILLIPS

The National Science Board's Merit Review Commission, of which you were the Vice Chair, recommended renaming "Broader Impacts" to "Societal Benefits." I appreciate the Commission's goal of emphasizing that NSF should consider both scientific advancement and benefits to society. However, the implementation risk is real. If proposals can claim societal benefits based on demographic composition or

adherence to social frameworks rather than on what the research actually produces, then "Societal Benefits" becomes a mechanism for non-scientific criteria to influence Federal funding.

a. Given that NSF staff reported far less clarity around Broader Impacts than Intellectual Merit, what specific safeguards are needed to ensure that "Societal Benefits" is tied to measurable benefits flowing from excellent science, rather than becoming a catchall for political, demographic, or ideological preferences?

Answer. One of the Board's core messages in its new policy is that we expect that all NSF awards should have the highest degree of merit on both criteria, uncompromised by ideology. Let me address your question in three parts, stipulating that implementation risk is real. Our report is predicated on two decades of implementation challenges for the current criterion; your concern applies irrespective of the proposed renaming.

To address it, first: clarity. Congress has helped clarify the goals of the broader impacts criterion twice in that period—a legitimate and important expression of the priorities of taxpayers. And yet confusion about the meaning and intent of this criterion persists and continues to be widespread in the research community. We believe renaming would reduce and even dissipate this confusion, particularly by making it clear that the terms "broader impacts" and "broadening participation" are not the same thing.

Second, as outlined in the report, transparency is the best safeguard that excellent science will be the hallmark of what it funds. NSF needs to show that all awards are unambiguously made on the basis of merit, and report publicly on its portfolio. This has been done with the merit review digest, but we can do much better, adopting portfolio approaches as suggested in our report.

Imagine, for instance, a financial investment-style annual prospectus that addresses goals, strategy, performance, risk, and portfolio composition. NSF should have command of its portfolio such that it is able to say clearly, at any time, what statutory dimensions of societal benefits are being addressed, and work with Congress and the Administration to set its strategic goals for societal benefits to accrue from the NSF portfolio. This is true for the knowledge production part of the portfolio, too. Transparency on *both* criteria, from scoring to outcomes, and on portfolio composition is the best guarantor of merit we can have.

Of course, there also needs to be *assurance* that the results are consistent with the intent. Congress will do its part, as will OMB. But a seated and empowered National Science Board, accountable to both Congress and the President, is also a critical safeguard as it exercises its oversight role with regard to NSF implementation of the policies for which the NSB is statutorily responsible for establishing.

Third, it is important to recognize that a choice between new knowledge and societal benefits is a false dichotomy. NSF-funded work does *both,* hence the two criteria.

Some of your concerns may be rooted in the fact that there are different views of what constitutes a societal benefit. This is rightly the domain of Congress. I offer two thoughts here. As emphasized in the report, many perspectives are needed to answer this question. While scientific expertise provides a critical and necessary perspective, scientists alone should not answer it. The people who will be affected, for good or ill, know best what would actually help. Look no further than the disagreements about what constitutes a beneficial application of a large language model. I'd also emphasize the original NSF Act purposes for the Foundation:

(1) To promote the progress of science; and

(2) to advance the national health, prosperity, and welfare; to secure the national defense; and for other purposes.

The two parts of the mission reflect the reality that science is not done in a vacuum—science is part of, not separate from, society. There is the practice of science, which is the pursuit of knowledge about the world around us because human beings are curious and like to know "why" things are the way they are. Curiosity is a basic human characteristic, but it's not obvious that satisfying this innate curiosity is something that the taxpayer should pay for if it doesn't have some potential other purpose. And that purpose is "societal benefit." This is where the scientific community and society, in the form of the government, meet. It is spelled out in the second part of the NSF mission above. While science itself is driven by curiosity and ingenuity, the connection to society requires a dialogue between those doing the science and the society paying for the work. As part of that dialogue, it is important to keep in mind that at the earliest stages of research, we often cannot predict the specific, concrete impacts that might arise from advances in fundamental knowledge, or how long it may take for those benefits to be realized. Nevertheless, it is incumbent upon

scientists to consider and articulate, to the degree possible, the potential benefits to the taxpayers who are funding their work.

Congress and the President are both critical. There are some national needs that, at different times, may require particular emphasis—for example, responding to scientific competition with adversaries or the need to ensure the country has enough STEM workers to accomplish national goals (since STEM education is a mission of the NSF). It is appropriate for the government to set priorities among all the possible societal benefits, being sure to honor the statute which specifies that NSF accomplishes the mission stated above "through funding research and education in *all* non-medical fields of science and engineering". The articulation of the specific areas of societal benefit that receive emphasis will vary over time as needs and political priorities evolve, and in adopting a portfolio approach to managing its awards, NSF can ensure that the agency is responding to priorities, meeting the *whole* of its mission, and being accountable.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. MARIA CANTWELL TO DR. JULIA PHILLIPS

Impact of Research Actions on the U.S. Research Enterprise

Question. America's strength in science and technology comes from an innovation ecosystem that supports discovery, trains talented researchers, and turns basic research into new industries. The University of Washington's Institute for Protein Design is a shining example. Led by David Baker, a Nobel Laureate, the institute combines AI with biotechnology to design entirely new proteins and could transform healthcare for millions of people. Since 2025, the Trump Administration has cancelled or delayed thousands of Federal research awards; proposed a new rule with the Office of Management and Budget (OMB) that would give political appointees greater control over research awards; and removed all sitting members of the National Science Board, including yourself. Altogether these actions are creating greater uncertainty across the research community.

Can you explain how these actions are impacting the research community today and what they could mean for the scientific breakthroughs and future industries that might otherwise be created in the United States?

Answer. America's lead in science and technology was never an accident. It was built, patiently, by investing in people and ideas over the long term. I spent my career watching that system deliver for our economy and for our national security. The actions you describe are damaging the foundations of this system, above all because long-term investments need long-term patience and cannot tolerate sudden major changes in direction or starts and stops in support. If you are a student deciding whether to devote several years of your life attending grad school, a university deciding whether to build a new lab or invest in expensive instrumentation, admit a student, or hire a researcher, or an industry deciding whether to partner with the Federal government, you already face immense uncertainty because research itself is unpredictable and the payoffs are uncertain. We don't know where the next discovery will come from or when it might have impact. If that student, researcher, university, or company faces yet another big risk on a long-term bet, it becomes only rational to do something else instead.

President Reagan had the right view:

> *"The remarkable thing is that although basic research does not begin with a particular practical goal, when you look at the results over the years, it ends up being one of the most practical things government does. This is why I've urged Congress to devote more money to research. It is an indispensable investment in America's future."*

Specific impacts include:

Cancelled and delayed awards. Already we are seeing fewer graduate students enrolling (both domestic and international) and *Physics Ph.D.s leaving the United States* at a record rate. Research programs are being interrupted, losing data and stranding significant investment already made. It's not just physicists. Early-career scientists through *Nobel laureates are seeking greener pastures abroad.* Other nations do not have to build a talent development system as good as ours. They need only recruit the people we are pushing out.

The proposed OMB rule. Political leadership should set the high-level strategy. The Board said as much in its 2025 report, *Merit Review for a Changing Landscape,* which recommended clarifying how award portfolios align with agency strategy and outcomes. But that same report identified the fundamental strength of NSF's oper-

ational model: a competitive process relying on expert review as the best method to award funds. Strategy sets the high-level expectations for the portfolio; within that guidance, peer review and expert program officers should remain the key arbiters of which projects are funded. The last thing we want is to waste taxpayer dollars funding research that is impossible, poorly conceived, unsupported by evidence, or wasteful. Giving political appointees the power to intervene in individual grant actions is inconsistent with best-in-class merit review. It lessens confidence in funding outcomes and lessens the incentive to propose the best science—the science that can withstand rigorous, nonpartisan, expert scrutiny. That is how a gold standard loses its luster. The proposed rule and related actions regarding visas and immigration also raise worrisome questions about publications, conferences, the unjustified and arbitrary termination of existing grants, and the future of international students and global collaborations that benefit us in so many ways.

Removal of the Board. Congress built the NSB into NSF's statute for a reason: no single official, of any party, should exercise unchecked control over the Nation's basic research portfolio. Science and engineering are too broad, too deep, and too important to our Nation's economic and geopolitical leadership for any one person to be expert across all dimensions of the agency's portfolio. Equally important, the Board has 6-year terms, staggered in a way that help policymakers and S&E leaders alike keep an eye on the *long-term* health of the Nation's S&E enterprise.

With no Board seated, there is no proper, unambiguously legal way for NSF to issue the largest awards, to move forward on new Major Research Equipment and Facilities Construction (MREFC) projects, or to prioritize those projects. Oversight of merit review integrity, policy implementation (including the new Merit Review Policy), performance, and risk have stopped. There is no one who can hire the next Inspector General or approve her semi-annual reports. Should Waterman award terms and conditions need to be updated, that would require Board action.

Broader strategy work has stopped: The Board cannot fulfill its duties, including working with the Director—when we get one—on NSF's annual budget request, consulting on the formulation of programs, or establishing (or changing prior) NSF policies.

More subtly, NSB's advisory voice has gone silent. Thanks to the hard work of the National Center for Science and Engineering Statistics (NCSES) and NSBO (NSB Office) staff, *Science and Engineering Indicators 2026* was published, but the one-pagers and policy pieces that enhance its usefulness to decision-makers have not appeared since the dismissal. Looking ahead to *Science and Engineering Indicators 2028,* whose process should have started this summer, the path for disseminating this vitally important data and accompanying Board advice is uncertain. Congress charged the Board with assessing the state of American science and engineering in a global context. That voice has been silenced at the precise moment we face our first true peer competitor since we rose to the challenge of Sputnik almost 70 years ago.

Further, the lack of a Board removes one of Congress' avenues for obtaining direct information or reports about NSF as in, for example, *Bridging the Gap: Building a Sustained Approach to Mid-scale Research Infrastructure at NSF* which was undertaken in response to language in the U.S. House Appropriations Committee Fiscal Year (FY) 2018 Report. One can imagine that in the near future, Congress might find it useful to have an independent body such as the (populated) NSB explore approaches to a coherent, sustainable STEM talent strategy.

What it means for the future. Taken together, these actions tell our most highly trained young people that pursuing a research career in the U.S. is extremely risky. On top of already-thin support for graduate study, students now cannot be sure of having the resources to finish their degrees, while facing diminished future prospects for research careers in the U.S. International students, who earn more than half of U.S.-awarded Ph.Ds in some critical and emerging technology fields, receive clear signals that they are not wanted (further reinforced by new visa restrictions), either to study or to remain post-degree and contribute to our STEM enterprise, while other countries welcome them with open arms. These actions also push established researchers to propose "safe" research to minimize their chance of seemingly capricious loss of funding. No one knows how much high-risk, high-reward research will never be conducted under this scenario. And NSF is stripped of strategic oversight and leadership at the moment it needs both most.

The Institute for Protein Design exists because, decades ago, this country funded basic research no one could yet justify commercially, and trusted expert review to select the projects and investigators with the most promise for advancing our knowledge and returning benefits to society. The same is true of LIGO, Google, and so many other dreams become reality that have transformed our world. As a country, we are taking actions that, intended or not, will ensure that the next such institute,

the one that should be founded here ten years from now, will not be established in this country. Other nations are out-investing and out-recruiting us. They are reclaiming the talent we trained, the people we invested in, including our own citizens. Why would they want to come back?

Protecting Independent Scientific Advice

Question. The President recently attacked the National Academy of Sciences (NAS) while threatening to cut off their funding, simply because NAS is highlighting climate risks to the judicial branch. Whatever the disagreement over a particular report, NAS has long provided independent scientific and technical advice to the Federal government and the courts.

Why are the National Academies important to sound Federal decision-making, particularly when policymakers and judges must evaluate complex or disputed scientific evidence? What could be lost if researchers or scientific institutions become less willing to provide independent advice on controversial issues?

Answer. While I am not qualified to address the particulars of that report, I do endorse the recent action by the National Academies of Science, Engineering, and Medicine (NASEM), all three of which operate together under a Congressional charter signed by President Abraham Lincoln in 1863. I think the reasoning in their *statement* is correct:

> *"The National Academy of Sciences was founded on the enduring principle that our Nation deserves the best available scientific knowledge. Our core mission is to deploy science in service to the Nation while employing procedures that are rigorous, nonpartisan, and that manage potential bias and conflicts of interest. When questions arise whether that standard has been met, we have an obligation to examine them honestly and act on what we find.. . .*
>
> *This assessment is about the process used to produce the chapter and not about the validity of climate science. The focus is on our own procedures and whether they were adequate to ensure the highest standard of objectivity that this institution requires and our Nation deserves."*

From my own, direct experience in other reports, I know that NASEM has a rigorous process for constituting committees that conduct consensus reports. We make every effort to ensure that multiple points of view, appropriate expertise, and relevant experiences are reflected in the committee membership. After a report is written, it undergoes extensive peer review, again with an eye to getting input from individuals with different points of view, expertise, and experience. This can result in a long process to produce a report, since all issues need to be resolved before publication, but it generally produces a credible report. It is critical to note that charges to NASEM study committees are complex. They require deep subject matter knowledge and significant deliberation and debate. Their findings and recommendations cannot be reduced to one or even a string of social media posts. In short, today's favored means of communication are inconsistent with what is needed to understand and debate the important and complex topics considered by NASEM reports.

Other NASEM products do not undergo the same process, so they can be faster to produce, which may be important under some circumstances; those are clearly labeled and still require a significant level of expertise and deliberation. The reader must pay attention to the type of product being read. Of course, everyone who is part of producing a NASEM product is a human being, hence fallible. And the information accessed by the groups who are producing products can be incomplete or even wrong, since the topics are often at the frontiers of knowledge and sometimes touch on sensitive information not widely available. These expert groups are sometimes called on to make predictions about the future based on known facts. Predictions are necessarily just that and NOT facts. The bottom line is that while the system is imperfect, as are all human systems, *I know of no institution that has a more rigorous process for producing technically informed, balanced products.*

Our world is more complex than ever, with ever more information that can be brought to bear on our problems. After decades of pressing the accelerator on our ability to get, store, manipulate, and use information, we now find ourselves at a point where using it well is often beyond the scope of any one person. AI tools are amplifying this problem in good ways and bad. But ultimately human judgment needs to be part of all of our decisions. In matters of science, engineering, and medicine, experts can help us understand complex, technical information. And today, everything important, from health, to security, to economy is built on science and engineering. In this world where research and knowledge are the new currencies of power, I cannot imagine our Nation's continued success if Federal decision-making ceases to be informed by scientific expertise. Why would we lobotomize ourselves?

Congress no longer has the Office of Technology Assessment. The National Science Board was dismissed. Many advisory committees across the Federal government have been dismissed. If we were to defund NASEM now, who would step up to help our country, our government? Even now, threats have chilling and polarizing effects, and I worry that some of our best scientists are being bullied into silence, while those who try to speak up step forward into an abyss. Our adversaries are staring at us with their mouths open and quiet glee. When NSB was dismissed, there were unprecedented requests from foreign media to speak with former Board members, including from China. Our competitors are dumbfounded. Losing NASEM would be another self-inflicted wound, hobbling our Nation in the global race for the future.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. JOHN HICKENLOOPER TO DR. JULIA PHILLIPS

OMB's Proposed Federal Funding Rulemaking

The Office of Management and Budget recently proposed a rule that would give political appointees broad power over Federal grantmaking, including the authority to deny or rescind Federal grants at any time.

A proposal like this would enable corruption, undermine American scientific competitiveness, and increase bureaucracy and red tape.

Question 1. Dr. Phillips, why should grantmaking processes and decisions be based on scientific merit and subject to a robust, independent peer-review system?

Answer. The 2025 NSB report, *Merit Review for a Changing Landscape* (the Merit Review report), identified the fundamental strength of NSF's process: a competitive process relying on expert review as the best method to award funds. Strategy, set by political leadership and the leadership of NSF, sets the high-level expectations of the portfolio; within that guidance, peer review and expert program officers should remain the key arbiters of which projects are funded. The last thing we want is to waste taxpayer dollars funding research that is impossible, poorly conceived, unsupported by evidence, or wasteful. Giving political appointees the power to intervene in individual grant actions is inconsistent with best-in-class merit review. It lessens confidence in funding outcomes, and it lessens the incentive for researchers to propose the best science, the science that can withstand rigorous expert scrutiny. That is how a gold standard loses its luster.

As discussed in the Merit Review report, there are opportunities to improve NSF's best-in-class merit review process. Of course, we expect that all NSF awards should have the highest degree of merit on both criteria—intellectual merit and broader impacts—uncompromised by ideology. We must improve our ability to ensure that this goal is being achieved.

The first issue is clarity. Congress has helped clarify the goals of the broader impacts criterion twice in the last couple of decades—a legitimate and important expression of the priorities of taxpayers. And yet confusion about the meaning and intent of this criterion persists and continues to be widespread in the research community. We believe the renaming the criterion to "societal benefits" would reduce and even dissipate this confusion, particularly by making it clear that the terms "broader impacts" and "broadening participation" are not the same thing.

Second, as outlined in the report, transparency is the best safeguard for effectiveness. NSF needs to show that all awards are unambiguously made on the basis of merit, and report publicly on its portfolio. This has been done with the *Merit Review Digest,* but we can do much better, adopting portfolio approaches as suggested in our report. Imagine, for instance, a financial investment-style annual prospectus that addresses goals, strategy, performance, risk, and portfolio composition. NSF should have command of its portfolio such that it is able to say clearly, at any time, what statutory dimensions of societal benefits are being addressed, and work with Congress and the Administration to set its strategic goals for societal benefits to accrue from the NSF portfolio. This is true for the knowledge production part of the portfolio, too. Transparency on *both* criteria, from scoring to outcomes, and on portfolio composition is the best safeguard we can have.

There also needs to be *assurance* that the results are consistent with the intent, provided, of course, that someone is watching. Congress will do its part, as will *OMB.* We also need a seated and empowered National Science Board providing oversight, informing portfolio strategy, and setting policy.

Third, it is important to recognize that a choice between new knowledge and societal benefits is a false dichotomy. NSF-funded work does both, hence the two criteria.

I recognize the fact that there are different views of what rightly constitutes a societal benefit. This is the domain of Congress. I offer two thoughts here. As emphasized in the report, many perspectives are needed to answer this question. While scientific expertise provides a critical and necessary perspective, scientists alone should not answer it. The people who will be affected by the work and its outcomes, for good or ill, are particularly well positioned to weigh in. Look no further than the disagreements about what constitutes a beneficial application of a large language model.

I would also emphasize the original NSF Act purposes for the Foundation:

(1) To promote the progress of science; and

(2) to advance the national health, prosperity, and welfare; to secure the national defense; and for other purposes.

The two parts of the mission reflect the reality that science is not done in a vacuum—science is part of, not separate from, society. There is the practice of science, which is the pursuit of knowledge about the world around us because we human beings are curious and like to know "why" things are the way they are. Curiosity is a basic human characteristic, but it's not clear that satisfying this innate curiosity is something that the taxpayer should pay for if it doesn't have some other purpose. And that purpose is "societal benefit." This is where the scientific community and society, in the form of the government, meet. It is spelled out in the second part of the NSF mission above. While science itself is driven by curiosity and ingenuity, the connection to society requires a dialogue between those doing the science and the society paying for the work. It is essential that the dialogue involves representatives of the government allocating funding for the work. As part of that dialogue, it is important to keep in mind that at the earliest stages of research, we often cannot predict the specific, concrete impacts that might arise from advances in fundamental knowledge, or how long it may take for those benefits to be realized. Nevertheless, it is incumbent upon scientists to consider and articulate, to the degree possible, the potential benefits to the taxpayers who are funding their work.

Congress and the President are both critical. There are some national needs that, at different times, may require particular emphasis, for example, responding to scientific competition with adversaries or the need to ensure the country has enough STEM workers to accomplish national goals (since STEM education is a mission of the NSF). It is appropriate for the government—Congress and the administration—to set priorities among all the possible societal benefits, being sure to consider the statute which specifies that NSF accomplishes the mission stated above "through funding research and education in *all* non-medical fields of science and engineering". The articulation of the specific areas of societal benefit that receive emphasis will vary over time as needs and political priorities evolve, and in adopting a portfolio approach to managing its awards, NSF can ensure that the agency is responding to priorities, meeting the *whole* of its mission, and being accountable.

National Center for Atmospheric Research (NCAR)

In December 2025, the Administration announced their plans to dismantle the National Center for Atmospheric Research, or NCAR.

For over 60 years, NCAR, a federally funded research and development center (FFRDC), has accelerated our country's ability to understand and predict atmospheric events like hurricanes, tornadoes, and fire weather.

NCAR's data, tools, and models inform a wide range of users including the National Weather Service and its ability to provide warnings and weather updates, wildland firefighters working on the ground and in the air, and our Nation's military and our situational awareness in operational environments.

Question 2. Dr. Phillips, how important are FFRDCs for not only advancing scientific progress but also maintaining our national security?

Answer. FFRDCs are found across many of the Federal agencies that have a role in the Nation's S&E ecosystem. FFRDCs are public–private partnerships operated by universities, nonprofit organizations, or corporations to meet specialized, long-term research and development needs of the U.S. government. They are prohibited from competing for work outside their government sponsorship and are designed to provide independent, objective, and highly technical expertise. The most recent list maintained by NSF indicates that the 42 FFRDCs are found in 10 Federal agencies.

A particularly important aspect of FFRDCs is their role in providing national services—research and knowledge that serves all citizens. The FFRDCs with which I am most familiar (the DOE laboratories, especially those of NNSA, and NCAR) have specific missions that are national in nature. Many are focused on a challenge that is truly national in scope, for example national security (as in the NNSA laboratories). Particularly in national security, the work of the FFRDCs is done in the

national interest. These entities are charged with staying out of the competition among companies and providing technical knowledge, research, and advice to the government without regard to outside interests and in support of other entities, including in the private sector, with regard only to best serving the national interest. That role has been vital, as attested by their many contributions to the nation, including next-generation, *high-resolution synthetic aperture radar systems* and other intelligence, surveillance, and reconnaissance systems and transferring the technology to a variety of private sector firms for manufacture and application-specific integration and deployment.

Other FFRDCs have roles in the national interest for which there is no natural private sector provider. The contributions may be of a pre-competitive nature (data, computational models, etc.) where it is in the public interest for the results to be broadly available (*e.g.,* in the case of NCAR, for weather prediction, etc.) All of these FFRDCs advance the frontiers of knowledge (in different ways) and provide clear national benefit in our scientific prowess, national security, and the well-being of our citizens. Other NSF-funded FFRDCs operate major scientific facilities, *e.g.,* astronomical facilities. These are world-class capabilities that advance the frontiers of knowledge and advance the technology that enables unprecedented observations and discoveries. While not the original motivation for some of these technologies, there are impressive ancillary benefits that accrue from their development that will be put to use in other applications—for example the various technologies that enable the Vera Rubin Observatory to achieve the incredible stability (even against earthquakes), speed, and image clarity required for the sky surveys it is conducting.

Without FFRDCs in this role, I worry that we would see the (with apologies for invoking the all-too-appropriate 2023 word of the year) the *enshittification* of information and assets that we collectively rely on. If we relied on the private sector for the forecasting resources and data NCAR provides we would pay again and again for the data, within and across companies, for worse information—and we would stratify, rather than democratize, access to high-quality, high-fidelity data and information. That is bad enough with scientific or economic work. But *we cannot ever accept the enshittification of our national security.* We cannot have the technical advice our government needs potentially held hostage by private interests and unavailable to *every* entity or mission that has a legitimate national need for it. FFRDCs are an important tool prevent that.

National Science Board

As you know very well, the National Science Board was established by Congress to be a non-partisan advisory board to inform science and engineering research and education issues in support of American scientific leadership.

In April, President Trump unlawfully terminated all 22 board members in April, including you.

Question 3. Dr. Phillips, if the NSB members had not been fired, what kinds of important functions would the Board currently be performing?

Answer. Congress built the NSB into NSF's statute for a reason: no single official, of any party, should exercise unchecked control over the Nation's basic research portfolio. Science and engineering are jewels for the present AND the future. They are too broad, too deep, and too important to our economic and geopolitical leadership for any one person to be expert across all dimensions of the agency's portfolio. Equally important, the Board has 6-year terms, staggered, in a way that have helped us keep an eye on the *long-term* health of the S&E enterprise.

With no Board seated, there is no proper, unambiguously legal, way for NSF to issue the largest awards, to move forward on new MREFC projects, or to prioritize those projects. Oversight of merit review integrity, policy implementation (including the new Merit Review Policy), performance, and risk have stopped. There is no one who can hire the next Inspector General or approve her semi-annual reports. Even the Waterman award terms and conditions are now fixed.

Broader strategy work has stopped: The Board cannot work with the Director—when we get one—on NSF's annual budget request, consult on the formulation of programs, or establish (or change) prior NSF policies.

More subtly, NSB's advisory voice has gone silent. Thanks to the hard work of NCSES and NSBO (NSB Office) staff, *Science and Engineering Indicators 2026* was published, but the one-pagers and policy pieces that enhance its usefulness to decision-makers have not appeared since the dismissal. Looking ahead to *Science and Engineering Indicators 2028,* whose process should have started this summer, the path for disseminating this vitally important data and accompanying Board advice is uncertain. Congress charged the Board with assessing the state of American science and engineering in a global context. That voice has been silenced at the precise moment we face a fully formed peer competitor.

Question 4. Dr. Phillips, did the firing of all NSB members hurt this country's ability to lead on the global stage in science, innovation, and competitiveness? If so, in what ways?

Answer. There is no other body in the U.S. government that fulfills the roles of the NSB. For the past 75 years, the Board has been a nonpolitical entity with scientific and technical credentials across the breadth of science and engineering—an entity qualified to provide oversight, and, until April 2026, unbroken continuity of leadership for NSF that is complementary to the role of the NSF Director. The six-year terms, combined with the breadth of expertise and experience of Board members, enables it to provide (1) long-term perspective and vision for the U.S. S&E enterprise, and (2) valuable insights and guidance on agency strategic priorities and investments and evaluate the performance of the NSF. NSF's roles in supporting fundamental science across all non-medical areas of science and engineering and in educating the STEM workforce are unique and rely on strategic guidance and oversight by individuals with science and engineering research credentials. Ensuring that NSF is supporting world-leading work in a world-leading way is the appropriate role of an experienced, apolitical group of scientists and engineers.

The NSB is also charged with advising on the state of science and engineering in the U.S. in a global context through its leadership of the biennial production of *Science and Engineering Indicators.* This enables the Board to speak about the U.S. position in S&E relative to other countries and to identify trends that signify threats to the preeminence we have enjoyed since WWII. The Board's collaboration with NCSES (National Center for Science and Engineering Statistics, the Federal statistical agency housed within NSF) is especially valuable in informing the Board's examination of the state of U.S. science and engineering, combining NCSES' state-of-the-art expertise in the relevant data sets and statistical methods with the broader context provided by the NSB. We cannot know what our position is on the global stage if we don't have rigorous, policy-neutral data.

Further, the lack of a Board removes one of Congress' avenues for obtaining direct information or reports about NSF as in, for example, *Bridging the Gap: Building a Sustained Approach to Mid-scale Research Infrastructure at NSF* which was undertaken in response to language in the U.S. House Appropriations Committee Fiscal Year (FY) 2018 Report. One can imagine that in the near future, Congress might find it useful to have an independent body such as the (populated) NSB explore approaches to a coherent, sustainable STEM talent strategy.

In short, the NSB provides scientific leadership, a long-term view, guidance, critical oversight, and a voice for ensuring that the U.S. has an unparalleled base of fundamental science and engineering talent, facilities, and support. All of these are vital contributions to the success of NSF and for our country's continued leadership in an intense global competition.

NSF and National Security

In your testimony, you highlighted that over the past quarter century, the U.S. has ceded to China its position as the foremost global research & development investor and high technology manufacturer.

The country that leads in science will lead in scientific standards, intellectual property, scientific communication, and commercialization. In other words, leading in science is national security.

While fields like semiconductors and artificial intelligence are often highlighted, leading in basic science remains to be the clear way in which we will win the battle for the next quarter century.

Question 5. Dr. Phillips, how does basic science interweave with applied science to advance scientific leadership and national security?

Answer. Science is a continuum. There is no bright line between "basic science" and "applied science." Many scientists and engineers straddle the two. For example, a scientist may read a paper that reports discovery of a new material that has interesting properties never seen before but goes no further. The scientist may think to herself that those properties might be just what is needed to build a better mousetrap. Since she knows something about catching mice and has the appropriate equipment, she sets out to build a prototype of a new sort of mousetrap. She has moved into applied science and engineering. The mousetrap may be very successful. But along the way, she also discovers some other properties of this material that surprise her, based on her knowledge of materials science. She wonders what it is about the material that gives it those properties. She starts investigating. How does this combination of properties arise in a single substance? This requires knowing a lot about the structure of the material. We're now back in the space of basic research. Going further, are there other materials with similar combinations of properties? Can we predict what they are or how to make them? This is all basic re-

search, possibly inspired by a particular use we have in mind. It is this interplay between curiosity to understand and the drive to solve a problem that is important that makes up the scientific enterprise.

The connection between basic and applied science and national security arises naturally. One aspect of assuring our national security is to ensure that we have a competitive advantage.

Technological superiority is an important piece of that, though not the only one, of course. Technological superiority means that you have world-leading capabilities that no adversary can match. No adversary can penetrate your secure systems—physical, computational, etc. Not only must you be world-leading in these areas, but you must also know as much as possible about the capabilities of your adversaries. They don't need to be as good as yours if they are very good at identifying and exploiting your vulnerabilities. Alternatively, they may have discovered some new physical principle that enables them to develop an entirely new capability that you don't see coming. Or they may be sufficiently creative to put known capabilities together in a completely new way. The bottom line is that they may be able to come up with ways to defeat our capabilities that we don't anticipate—this is technological surprise.

Its upstream counterpart is *scientific* surprise. NSF's most important purpose is making sure that our country is never blindsided by new knowledge or some fundamental discovery made somewhere else. The more we disengage from the global scientific and engineering community, the more we leave ourselves open to surprises that come from not knowing what the smart people beyond our borders are doing and thinking about. This is a very real danger posed by some aspects of the proposed OMB rule regarding restrictions on publication, attendance at conferences, and international collaborations. It could be a technology that leaves us in the dust economically or a discovery that puts our Nation's continued existence at risk. We in the U.S. are not used to thinking in these terms. For decades we have assumed that the U.S. will remain the place where a majority of research breakthroughs are made. But today, with China taking the lead on research expenditures, talent development, and other key metrics of S&E leadership, and with policy changes that constrain our ability to collaborate—even with allies—and attract global talent, I worry that our lack of a commensurate response to the intense S&E investments and advances of our competitors gives the appearance of complacency to all who read the news and is already putting our national security at risk. It is a competition. It is a race. It is a long game. The consequences to our liberty and prosperity will be real. And where we are not actively hurting ourselves or succumbing to distractions we are fiddling while our foundation crumbles.

RESPONSE TO WRITTEN QUESTIONS SUBMITTED BY HON. LISA BLUNT ROCHESTER TO DR. JULIA PHILLIPS

The STEM Workforce

Question 1. The United States is making significant investments in emerging technologies, but those investments will only succeed if we have a strong pipeline of scientists, engineers, technicians, and skilled workers to support them.

a. Beyond increasing research funding, what are the most important actions Congress can take to strengthen America's quantum and broader STEM workforce over the next decade?

Answer. In recent years the Board has been alarmed by the risk that the best and brightest foreign students, on *whom we have come to rely* (especially in critical technologies) might choose to stop coming to the U.S., or have their governments decide that for them. Since the Board issued its 1-pager, we face the added risk of these students being denied visas to complete their education in the U.S. or to stay and work. We are already seeing measurable impacts. We recommended derisking through Federal investments in domestic talent at a scale commensurate with the problem—many billions of dollars—in partnership with state governments and the private sector. Drawing inspiration from the last time we rose to a national technological threat in the aftermath of Sputnik and recognizing that this investment is essential for national security, NSB *proposed an "NDEA 2.0"* centered on three pillars.

1. *Where possible, don't create new programs. Invest in local STEM education and workforce ecosystems:* Scale what is working, with a focus on critical needs and opportunities to stack dollars across sectors (all levels of government, private sector, and philanthropy). The Board did not recommend specific programs, but our work identified several promising candidates, for instance:

- *Matching and block grants for regions to scale successful approaches:* Inspired by the 1958 NDEA Title III, which provided matching grants to schools for equipment, NDEA 2.0 would support community-led initiatives that work and can scale. Funds would be responsive to community demand signals and incentivize local, state, and regional planning on scaling up S&E workforce development. Promising avenues include:
  - *STEM enrichment:* Scale STEM afterschool/summer programs—especially those that are funded by stacking dollars across sectors—for all students
  - *Access to tools:* Modernize, renovate, and repair preK–12 and technical STEM learning facilities
  - *Experiential learning for post-secondary 2-year, 4-year, and graduate students:* Scale successful co-op models that facilitate hands-on, multisectoral research experiences in critical technology areas. Provide matching funds for internships in industry and government sectors

2. *Invest directly in STEM students and workers in critical areas:* Directly incentivize students and non-STEM workers to go into critical areas and meet workforce needs. Directly empowering students with funds and choices creates stronger incentives and more flexibility when compared to funding that goes to an institution on whom the students then depend. If we want more talent we should buy more talent! I note that the Trump Administration seems to share this view, for instance supporting more NSF Graduate Research Fellows (GRFs). I would call for doing even more, faster, and offer two specific targets for your consideration:
   - *Create 5,000 additional U.S. citizen NSF GRFs per year in critical technology areas:* Modeled on the NASA Space Grant Consortium.
   - *Fund 8,000 new 2-year and 4-year scholarships for high-achieving students in STEM areas of national need.* Expand targeted scholarship-for-service programs (Defense Civilian Training Corps; Federal Cyber Scholarship for Service) for 2-and 4-year STEM college students in critical areas. We should not limit that to advanced students, either but seek to equip skilled technical workers for emerging industries. One specific example:
     - *Create multi-sectoral approaches to train and reskill skilled technical workers:* Extend the CHIPS & Science Act model for microelectronics workforce development to other critical technology areas, *e.g.*, Quantum and other emerging areas, encouraging private sector partnerships, direct support of cross-sectoral training, and hands-on skills development.
3. *Address the STEM teacher shortage:* Recruit 200,000 preK–12th STEM teachers, retain 100,000 STEM teachers past their 5-year teaching mark, and expand the STEM community college workforce. To do this, some ideas:
   - *Recruit and retain STEM educators with financial incentives:* Offer tax breaks for STEM teachers for the first few years of their teaching career
   - *Recruit and retain STEM teachers through critical area-specific preparation and professional development programs*
     - Establish a multi-sectoral funding consortium to increase the number of teachers in critical areas and mathematics. Provide matching funds to states to identify and sponsor teachers for continuing education, such as for STEM degrees at state colleges and universities.

- *Restore the original Eisenhower Professional Development Program* in partnership with the private and philanthropic sectors.

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