Testimony of
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"Oversight and Examination of the National Science Foundation's Priorities for 2025 and Beyond"

What of the Future?

> *"The only limit to our realization of tomorrow will be our doubts of today."*
> *- President Franklin D. Roosevelt*

Chairman Lucas, Ranking Member Lofgren, Chairman Collins, Ranking Member Stevens, and members of the subcommittee, it is a privilege to testify before you today. I am here to deliver a message of appreciation and progress, but also one of concern.

Thank you for your leadership on the CHIPS & Science Act, a bold blueprint for strengthening the nation's science and technology (S&T) ecosystem. Due to your vision, the National Science Board (NSB) and the National Science Foundation (NSF) are defining a 21st century agency that connects and bridges basic research and translation, inspires and develops the next generation of STEM talent, and delivers benefits for all Americans.

Since the enactment of CHIPS & Science, NSF has worked to strengthen research security; it has established the Directorate for Technology, Innovation, and Partnerships (TIP); and it created a new signature program – Regional Innovation Engines – and made the first Engines awards. Meanwhile, NSF is delving deeply into the complex, interdependent issues that have thwarted the STEM aspirations of too many of our young people, to our country's great detriment. In short, NSF is embracing new directions while maintaining its core research mission.

Science and technology are now indispensable pillars of our nation's hard and soft power, of our national security, and our economic prosperity. Equally importantly, science and technology are shaping and reshaping our everyday lives, as decades of basic and applied research yield breakthroughs such as mRNA vaccines and generative artificial intelligence (AI) – seemingly overnight.

The United States is still the best place in the world for science and technology R&D. However, if we fail to make the necessary public investments in our national S&T knowledge infrastructure – our people, our laboratories, and our research institutions – we endanger the very foundation on which our innovative and dynamic private sector businesses depend for continued success. Meanwhile, we face increasingly fierce global competition in technology areas critical to our economic competitiveness *and* to our national security – including artificial intelligence, semiconductors, quantum computing, and post-genomic biology.

The warning lights are flashing red, as shown by the 2024 edition of the National Science Board's *Science and Engineering Indicators*:

- Among advanced economies, U.S. K-12 students have long been merely "middle of the pack" in STEM performance. Furthermore, data from 2022 show that what little gains U.S. students made in mathematics proficiency in the past 20 years were erased during the pandemic. These declines are the largest for individuals from race and ethnicity groups already marginalized in STEM, and those from low socioeconomic status households.
- Even as our domestic STEM talent crisis accelerates, federal funding for R&D, when adjusted for inflation, is essentially flat. Meanwhile, the research and educational capacity of other nations continues to grow. With each *Indicators* cycle comes news that People's Republic of China (PRC) has surpassed us on another key S&T metric. The PRC is closing the gap with the United States on R&D expenditures and has surpassed the United States in STEM doctoral degree production, research publications, patents, and knowledge-and-technology intensive manufacturing.

I remember a time when we believed anything the United States could dream, we could do. In the aftermath of World War II, we were bold and audacious, and yes, we made some terrible mistakes, but we rebuilt Europe and Japan, making deep and lasting allies of former enemies. As a grateful nation, we sent millions of returning veterans to college via the GI Bill, to the enduring benefit of our society.

We conceived and constructed public goods like our national highway infrastructure, we cleaned up our air and water, and – belatedly – we looked within ourselves and began righting longstanding wrongs and injustices.

And yes, amidst a Cold War race, we went to the moon. Drawing on the resources and talent of the world's richest and most powerful national state, we stretched our hand into the 21st century and pulled back just enough technology to make that age-old science fiction dream a 20th century reality.

It seems to me that we have lowered our expectations, choosing to believe the future is unlikely to be better than the past. Even as S&T becomes ever more critical to our economic and national security, critical components of that innovation ecosystem system are not keeping pace with our competitors. Other countries, having watched and learned from the U.S. playbook, are investing heavily in discovery, innovation, and STEM talent.

Meanwhile, our country is caught up in our internecine strife, a decline in trust, and the myriad other challenges surrounding us. Having lost sight of the profound opportunities before us – and they are truly astounding – we have yet to find a path to deliver fully on the promise of CHIPS & Science. While some elements of private sector R&D are thriving, as a nation, we are not moving at the speed of some of our allies and competitors.

Instead, all too often we have chosen to limit our ability to take the risks and pursue the big ideas that yield transformational benefits for the American people. As leaders and policymakers, we know this, but knowing it is not enough; we must act based on that knowledge and the strength of our convictions.

Global leadership in S&T is neither an abstraction nor an empty slogan. It is fundamental to our national power, safety, prosperity, and happiness. The People's Republic of China is not infallible. It has problems of its own, and the United States has acted forcefully to limit its ability to import some critical technologies.

The future is ours to win. The only thing stopping the United States from continuing to be the undisputed world leader in S&T is *us and our vacillation.* We must rekindle our passion and shake off our malaise and uncertainty.

Let me be clear. An even brighter future is still out there – for *all* Americans. It is ours for the taking, but we must act with vision and commitment to secure that future for our children and our grandchildren.

Accomplishments – and Alarms

> *"Knowledge is power; knowledge is safety; knowledge is happiness."*
> *- President Thomas Jefferson*

The United States now spends more than 3% of its GDP on research and development (R&D). This headline achievement reported in *Indicators 2024* is a long-desired milestone, and we surpassed it. In 2021, the United States spent 3.5% of GDP on R&D ($806 billion), and preliminary estimates are that this grew even further in 2022. This "R&D intensity" level – which predates investments made via the CHIPS & Science Act – exceeds that of most of our peer R&D-performing nations, including the PRC and many European countries. The United States also invested more on basic research than any other economy – $119 billion in 2021. The magnitude of these investments in R&D clearly demonstrates that S&T is the engine powering our innovation economy.

We should justifiably celebrate the fact that the United States is now spending more than 3% of its GDP on R&D. However, on closer inspection, the story is more nuanced and sobering. Business sector funding drove the growth in U.S. R&D in the last decade, and nearly 80% of that investment was in experimental development – the stage when the promise of near-term commercial benefit is both obvious and real. Private sector R&D is also highly concentrated, clustering in a few key sectors, notably information technology and pharmaceuticals. Over the 2011-2021 period, although absolute dollars of federal funds for R&D increased, adjusted for inflation, federally funded R&D was essentially flat and fell below 0.7% of GDP. Overall, federal funding for R&D grew at a 1.5% rate – less than half the rate of GDP growth, and below the rate of inflation.

We can all applaud the U.S. private sector's vitality and dynamism. However, business R&D is not a substitute for federal R&D; the two are complementary. The former, for all its vibrancy, ultimately depends on the robustness of the latter. Simply put, the private sector relies on the Federal government to make the crucial initial bets on new and unusual ideas. Many of the S&T advances that underpin today's commercial technologies and industries are rooted in research conducted decades before practical applications and innovations were realized.

As the NSB noted in *Vision 2030*, Federal support for research is necessary to

> *… remain globally competitive in fields 'of the moment' and to create the research environment and basic knowledge that will yield the next revolutionary advancement. While industry is well positioned to advance knowledge in targeted fields, only the federal government can invest across all fields, across the nation, at scale, and over sufficiently long-time horizons to create new knowledge that will help us to address future security, health, and economic challenges.*

Likewise, while businesses train and upskill their employees, the private sector does not and cannot broadly educate and train the STEM workforce. Hence, Federal, state, and local investment in the development of domestic STEM talent is essential to educating and supporting the next generation of STEM innovators, researchers, and skilled technical workers.

Talent is the bedrock of any nation's S&T infrastructure. In a knowledge-driven STEM economy, those countries that nurture and educate their talent will flourish. *Trained and talented people* drive innovation by carrying promising ideas from the laboratory to the workplace. It is therefore deeply worrisome that the United States is failing to adequately nurture its domestic talent base – in both numbers and diversity – leaving far too many behind. Consequently, we remain highly reliant on recruiting and retaining foreign talent.

In addition to dependence on a robust and highly qualified talent base, the private sector's success rests on a foundation of public investment in discovery research across all fields. Just as the private sector relies on federally-supported physical infrastructure such as our public highway system, our businesses, large and small, rely on this publicly-funded S&T knowledge infrastructure. The implication is clear and compelling – the current surge in U.S. private sector R&D is not sustainable if our nation continues its underinvestment at the Federal level in both ideas and talent.

With that backdrop, I am not here today to just ask for you to fund NSF at the FY25 request level, and to get us back on the CHIPS & Science authorization trajectory. Of course, the NSB and NSF want that, and we believe doing so is necessary to ensure our nation's future security and competitiveness. Rather, I am asking for more. I am asking us to dream bigger dreams and, as famed Chicago architect Daniel Burnham once wrote to, "make no little plans."

While I believe that a better future begins with better dreams, dreams are just the beginning. We have to follow through – we have to dare, and then do, boldly and without qualification. I think all of us, on this committee and at NSF, know the tremendous potential and capabilities of the American people, when we rally together, to do extraordinary things, things that dazzle and astonish the world. We have the potential for scientific and technological advancement, the potential to solve societal problems, and the potential to deliver a better life for people across the country, in every community, from east to west, north to south, and rural to urban. We must leave no one behind.

We must find a way to inspire our fellow Americans with the promise of S&T and translate that inspiration into participation – by attracting and retaining domestic talent from every demographic and from every corner of the country and connecting them via vibrant STEM education and fulfilling careers.

We must prioritize – and then sustain – federal investments in research. In CHIPS & Science, Congress called for a National Science and Technology Strategy that will, in the words of Chairman Lucas, ensure "a comprehensive, whole-of-government approach to research and development, improving coordination between federal agencies, and a more strategic approach to prioritizing our resources."

This strategy is vital for identifying the gaps and strengths in our national research portfolio and highlighting key opportunities for federal investment.

Though necessary, it is not enough to merely write a science and technology strategy. To deliver benefits from research to Americans and stay ahead of our centrally-organized competitors, I believe that the United States needs a federal S&T organization that is empowered to execute that strategy – to lead interagency efforts, to coordinate and partner with academia and industry, and be accountable for progress against that strategy.

Based on my decades of science and technology experience, I propose two ideas for your consideration. First, the United States should pursue a "National Defense Education Act (NDEA) 2.0" to develop domestic STEM talent at all educational levels. Second, Congress should explore the structural obstacles to implementing and delivering on a whole-of-government national strategy for science and technology.

NDEA 2.0

> *"It is no exaggeration to say that America's progress in many fields of endeavor in the years ahead – in fact the very survival of our free country – may depend in large part on the education we provide for our young people now."*
> *– House Report Language for the NDEA (1958)*

When I was a child, we drank TANG and dreamed of being astronauts. Envious of my first-grade classmate's Mercury space capsule pencil sharpener and confident that trading part of my first-grade school supplies was well worth it, I closed the deal. I never regretted it, not even for a moment.

This was a time when the country's best and brightest wanted to work on the space program, in every capacity imaginable. Every few months, it seemed something new and amazing happened – satellites, transatlantic broadcasts, and color TVs. As the New York World's Fair highlighted these and other wonders, it seemed anything was possible, even going to the moon.

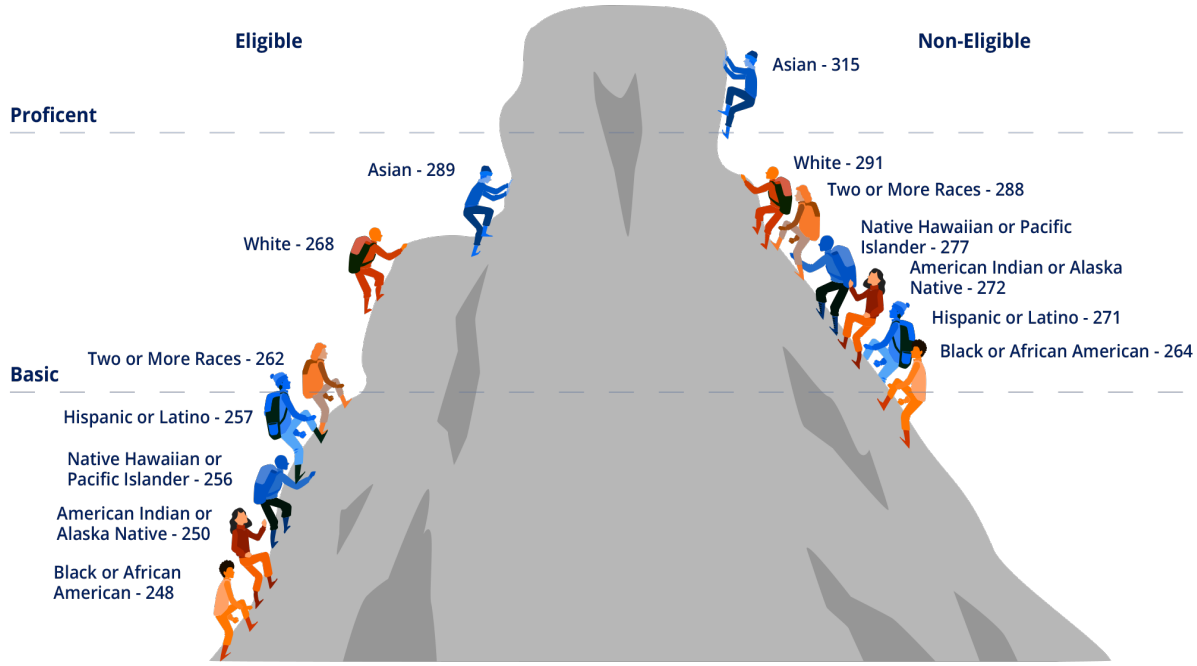
The future was here – we could feel it, and we were a part of it.

Like many of you, I was a child of the National Defense Education Act (NDEA). Signed in 1958 by President Eisenhower in the wake of the Soviet Union's Sputnik satellite launch and extended by President Johnson in 1964, the NDEA consisted of a suite of educational investments to "insure [sic] trained manpower of sufficient quality and quantity to meet the national defense needs of the United States." The NDEA's provisions to strengthen our national capabilities in science, mathematics, as well as select modern languages, were expansive. They ranged from graduate fellowships to financial assistance to encourage Americans to become primary and secondary school teachers, to support for purchasing STEM equipment and material for preK-12 classrooms, to programs to enhance pre-collegiate STEM teaching, to career counseling for high school students and vocational training. In its first decade, the NDEA investment totaled $3 billion or *$21 billion in 2017 dollars*; state matching funds for equipment and material made those dollars go even further.

The genius of the NDEA was that its investments channeled the inspiration that was all around us into participation in the scientific and engineering enterprise. It created opportunity where little had existed before. As the grandson of a sharecropper with a third-grade education, and the son of an Arkansas Ozarks sawmill worker with a fifth-grade education, the NDEA touched even me, giving me hope that a

STEM future could be mine. Teachers, books, simple, hands-on experiments – they set me on a path of STEM wonder and opportunity that sustains me to this day.

Some six decades later, the array of advances and new frontiers available to inspire and excite a new generation of Americans about STEM is larger than it has ever been. Yet today, we are not making the investment necessary to turn inspiration into participation for enough of our young people. Our current predicament is the result.



Average Scores of 8th Grade Students on the Main NAEP Mathematics Assessment, by Race, Ethnicity, and Eligibility for Free or Reduced School Lunch: 2022 (*NSB Talent is the Treasure, 2024*)

For decades, we have known that there are significant problems in public preK-12 education. Studies have long shown that students who are not performing at grade level in mathematics in the 8th grade do not later major in STEM subjects. Now, post-COVID-19, we face a full-blown crisis.

A national mathematics assessment in 2022 captured the largest decline in scores for 4th and 8th graders over the past 33 years. Alarmingly, the declines were the largest for individuals who are Black, Hispanic, from low-income families, or who are already scoring in the lowest 10th percentile – all groups that are already underrepresented in STEM. These sobering findings come after a decade of pre-COVID-19 test score stagnation that places U.S. students no better than the middle of the pack of developed countries in mathematics and science.

Even for students who have sufficient preparation and desire to pursue post-secondary STEM studies, the cost of those studies can be a barrier. Higher education costs, the percentage of students borrowing to finance their education, and the amount of total student debt have all grown in recent decades. Pell grants, even with the recent increase, are not keeping pace. Additionally, some higher education institutions charge higher tuition for STEM majors, creating a disincentive to major in STEM for

undergraduates for whom immediate, near-term costs outweigh the longer-term wage gains associated with STEM degrees.

The challenges in K-12 STEM education and cost barriers to post-secondary STEM degrees come at a time when the U.S. STEM workforce is now *one quarter* of the total U.S. workforce and is spread across all 50 states. There are 38 million people in the United States who use STEM skills in their jobs, including 19 million skilled technical workers without a bachelor's degree. Those numbers will only increase as companies expand their STEM workforce and their R&D investments in response to rising global competition.

As this committee knows well, the U.S. has insufficient numbers of domestic workers with STEM knowledge and skills to meet employer needs in critical and emerging technology fields and in national security domains. To fill this demand, the U.S. relies on foreign-born individuals – for example, over half of U.S. engineers and computer and mathematical scientists at the doctoral level are foreign-born. This international talent is a major strength for the U.S. R&D ecosystem. However, as other nations vie for STEM talent and increase their own domestic job opportunities, it is not a given that the United States will continue to be the preeminent destination for internationally mobile students.

The United States should continue to offer a welcoming environment to students from around the globe – and implement policies that entice and enable them to work in the United States after they receive their degree. Yet this is not enough; many security-sensitive jobs require U.S. citizenship, and our current outsized dependence on international talent is a vulnerability.

To maintain our nation's lead in S&T, we must invest in our domestic students and workforce. Talent is the treasure that defines our society and its future. In the CHIPS & Science Act, Congress provided semiconductor workforce development funding because you realized that to successfully reshore semiconductor manufacturing, we would also need workers to staff the fabrication facilities. This is a success story – but one that must be replicated for other critical and emerging technology fields, including AI, quantum computing, and biotechnology. We must invest in our people – they are the future and the guardians of our economic competitiveness and our national security.

I suggest that it's time – in fact, well past time – for a 21st Century National Defense Education Act (NDEA 2.0), that would inspire – and enable – a new generation to participate in S&T. It is not only practically and economically necessary to secure our future; it is morally and ethically right. STEM jobs pay better and are more recession-proof than other jobs at the same educational level. Nor can any just and equitable society leave large fractions of its population or regions of its country behind, lacking the knowledge and skills to compete successfully in a STEM-driven economy.

If we want to ensure the fruits of S&T continue to redound to our national security, prosperity, and well-being, we must act, and act now. We need to mobilize *all* our country's assets – government (at all levels), industry, academia, and non-profits – to address our growing challenges and the clear and manifest opportunities for discovery-fueled innovation. Just as the original NDEA, over the course of 14 years, galvanized new educational processes and partnerships, expanded educational and economic opportunities, and positioned the United States for future success, so too can a 21st century NDEA. The idea and its implementation must be bigger than one agency, one budget, or one Administration. In short, a 21st century NDEA is not just about investing in the future, it is about encouraging and unleashing talent – as it always has been.

We have long known that the quality of preK-12 STEM teaching is one of the most critical elements for student success; it is about sharing the passion and the wonder of discovery, grounded in scientific principles. Unfortunately, far too many of our preK-12 teachers have limited expertise in STEM subjects, and there is a dire shortage of qualified STEM teachers across the country. Therefore, NDEA 2.0 should directly invest in recruiting, retaining, and upskilling STEM teachers nationwide at every grade level. To recruit more STEM teachers, NDEA 2.0 could offer a combination of loan forgiveness and targeted scholarships. NDEA 2.0 could also create accessible pathways to enter STEM teaching via non-standard paths, such as "learn while you earn" programs for teacher's aides and other paraprofessionals currently working in schools and fast-track education certificates for STEM professionals who want to bring their knowledge to the classroom.

To enhance pedagogical outcomes and provide continuous learning opportunities, NDEA 2.0 could fund regional summer STEM teaching institutes that would offer a paid professional development opportunity for teachers to upskill and enhance their STEM knowledge and teaching techniques. To promote STEM teacher retention, NDEA 2.0 could also invest in induction programs for beginning teachers. Such programs, already in existence in some states, let districts take a different approach to onboard and integrate first time teachers that effectively supports them through the transition into the classroom. Together, such a package of programs could help teachers develop strong STEM competencies and bring the best research-based STEM pedagogy and practices to the classroom, informed by the needs and opportunities in each community.

At the post-secondary level, NDEA 2.0 could create "STEM Talent for America," a national service program for undergraduates. Such a program, modeled on the Defense Civilian Training Corps, could offer 2- or 4-year STEM scholarships in return for fulfilling a post-graduation national service requirement. Likewise, NDEA 2.0 could expand STEM graduate fellowships (building on and expanding programs such as NSF's Graduate Research Fellowships and Entrepreneurial Fellows Program, and the Department of Defense's SMART scholarships), particularly in targeted critical technology areas. We should also consider whether requirements for national service should be added to some of those fellowships to address the federal workforce STEM talent needs.

We know the truth. This is about the future, but it is also about something entirely secular, but deeply holy – the hopes of parents and the dreams of children. In those hopes and dreams rest the transgenerational trust that the future will be better than the past, that our children's future will be defined only by the magnitude of their talent and the scope of their dreams. Our future national security and economic competitiveness rest on us unleashing that talent and nurturing their dreams.

Competing More Effectively

> *"Science, engineering, and technology have combined to become a basic underlying force in American life – a force that America has shared with the world to the ultimate benefit of all mankind. Now, as we enter our third century, science, engineering, and technology are more important than ever in meeting the challenges and opportunities which lie ahead for this Nation and the world."*
> *- President Gerald R. Ford*

In an era of increased and accelerating global S&E competition, when scientific advancement, economic competitiveness, and national security are inextricably intertwined, our federal R&D ecosystem needs to move at the speed of science and innovation. Alas, it does not.

For nearly eight decades, the partnership among government, university, and industry has been a hallmark and strength of the U.S. R&D system. In this model, government builds the public infrastructure for R&D, via federal funding of basic research, and federal, state, and local investment in STEM education and workforce development. Colleges and universities conduct discovery research and post-secondary institutions of all types educate and train students. Industry, drawing on the stockpile of ideas and talent enabled by government and educational institutions, and supplemented by in-house R&D, translates ideas into products and services that improve our health, security, and quality of life.

I have been privileged to see this ecosystem from different angles and benefit from the synergy of this triumvirate, as an academic researcher in computing and computational science at four of our great public research universities (Illinois, North Carolina, Iowa, and Utah), as a corporate leader at one of the world's largest technology companies (Microsoft), and as a federal STEM policy participant (the U.S. President's Council of Advisors on Science and Technology (PCAST), the NSB, and a wide variety of government agencies and national laboratories).

However, as we face greater competition from centrally-directed nation states, the success of our R&D ecosystem will also depend on our ability to coordinate and align our S&T activities across sectors, federal agencies, and Congressional committees – *quickly and nimbly*. Numerous reports, including several by NSB, have observed that for all the creativity generated by our decentralized system, there are significant inefficiencies. To stay competitive, we will need more coordination and partnership among government, academia, and industry to speed the translation of research, develop talent in areas of national need, seed STEM-based economic development nationwide, and inject critical technologies into our national defense ecosystem.

In the CHIPS & Science Act, this committee advocated for two potentially powerful tools to drive this effort: a Quadrennial S&T Review and a National S&T Strategy.

I concur that we need to chart and execute a national S&T strategy. I also worry that a white paper will not lead to coordinated, determined actions with measurable outcomes. Why? First, because our current federal S&T structure does not have an entity charged with executing such a strategy across the federal government; inevitable interagency rivalries and fragmented Congressional jurisdictions limit coordinated execution. Second, we lack the mechanisms to manage the needed partnerships with academia and industry over the long term. Successful strategies must be sustained across election cycles.

Today, we find ourselves in a world that Vannevar Bush envisioned in 1945 – one where S&T is *the engine* of American prosperity, security, well-being, and global standing. However, the global landscape has changed drastically since 1945. China is our biggest competitor. The pandemic worsened the chronic challenges of U.S. STEM preK-12 education. Business R&D now dominates the U.S. S&T ecosystem. Meanwhile, our federal S&T structure still reflects yesteryear.

Today's panoply of science agencies, Congressional committees, and an ever-growing number of interagency policy committees that cover topics ranging from AI through nanotechnology to quantum reflect our recognition that such matters are major national priorities with critical import, requiring dedicated stewardship and either permanent or semi-permanent structures.

For too long we have layered an increasing number of bureaucratic and procedural patches atop our existing structures. I believe we need to acknowledge the truth – the time has come for a fundamental reconsideration of our federal S&T apparatus if we are to compete successfully in the global race to the future.

The radical changes in the R&D landscape call for a new approach that maintains the benefits of our distributed system while still positioning our nation for competitive success. Facilitating a truly national S&T strategy will require the ability to effectively and efficiently execute a whole-of-government effort, prioritize resources, and work hand-in-hand with our industry and academic partners, while being held accountable for progress toward agreed upon national goals.

I want to be crystal clear. I am not advocating for fully centralized and executed control – such is the height of foolishness. But the grassroots, bottom-up, almost entirely distributed process we so often now employ is simply not sufficient in this era of accelerated innovation and intense international competition.

Although every Congress and President have the constitutional right to change approaches, science and technology move at their own timescales; consistency and perseverance are required. Given the importance of S&T to the nation – including to our national security – we cannot afford to continue losing valuable institutional knowledge, time, and momentum with each election.

My ask is that this committee hold a hearing to explore this question. I believe real change is required if we are to compete successfully with China and other nations.

Together, Let's Dare Mighty Things

> *"That is happiness; to be dissolved into something complete and great."*
> *– Willa Cather*

For nearly 75 years, NSF has embodied Vannevar Bush's vision, funding groundbreaking basic research across every field of science and engineering, from astronomy to zoology. NSF has launched and supported individuals whose careers as researchers, educators, entrepreneurs, and innovators are embedded in every sector of our economy. With his conceptualization of science as an endless frontier, Bush's words appealed then as now to a nation that was a major actor on the global stage. The premise that what we know pales into insignificance compared to what might be learned and discovered remains compelling and tantalizing, and Bush's call for unfettered scientific exploration still speaks to our ideals and our deepest yearnings.

Beyond the endless and ineffable desire to know, the fruits of science and engineering discovery are the foundation of our country's continuing global stature. They are also central to addressing Americans' "kitchen table" concerns, such as finding a good job, improving their health, maintaining a clean environment, and keeping their children safe, both physically and online.

As important as they are, the fruits of our research and innovation are but artifacts of U.S. leadership. It is in the daring and the doing – in tackling ambitious projects and challenging ourselves to achieve extraordinary advances – that the United States asserts and secures our power and our place in the world.

In that spirit, I ask us to put aside our differences and embrace our common values, to be a community of dreamers who both dare and do. A community that seeks new insights and knowledge, nurtures our young people, and is imbued with a deep sense of ethics, personal responsibility, and empathy. A community that is unwaveringly committed to a better future for everyone.

This is a call to action – bigger, bolder action. We must not coast on the glories of the past, but march decisively toward the opportunities of the future. We can and must, in the words of Theodore Roosevelt, "dare mighty things," matching our rhetoric with our deeds. It is in the daring and the doing that the U.S. asserts and secures its power and place in the world.

The need is real. The opportunity is great. The time is now.