MARCIA MCNUTT

For a More Competitive US Research Enterprise, the Work Begins Now

Here's what we need to do to keep American science strong.

The US scientific enterprise has for decades been a juggernaut for innovation, economic growth, and lasting national security and prosperity. However, as the head of a premier US science organization, I am growing increasingly alarmed by worrying trends that threaten to undermine our global leadership in science and our ability to continue producing the advances that our nation and world have long depended upon.

As a result, I felt strongly that it was time to do what we scientists do best—take a hard look at data to get an informed assessment of the health of the US research enterprise and current trends in science leadership. I shared my findings publicly in June when I delivered my first State of the Science address. Modeled after the State of the Union addresses that US presidents give each year, the goal of my speech was to explore actions we need to take now if American science is to remain strong and successful in the years ahead—and to spark a call to action among researchers, policymakers, university administrators, philanthropists, and others in the public and private sector.

In my speech, I presented data on the status of US scientific leadership in the world. While we still invest the most money in research and development, China's rate of investment in R&D is growing at twice that of the United States, and China is now on track to surpass US investments. That investment is also producing more research output—for example, China's global share of drugs in phase I to III trials has grown from 4% in 2013 to 28%. And China is not the only country making this investment. Other nations are understandably following the US model of investing in STEM education and basic research to fuel their economic growth and prosperity. This, in turn, is increasing the fierce global competition for STEM talent. The United States is especially reliant on foreign-born STEM students and workers, who fill some 20% of STEM jobs that require an undergraduate degree. They also make up more than half of graduate and more than a third of postdoc STEM applicants at universities.

Recent decades have seen major shifts in how the US research enterprise operates. For instance, although the federal government remains the largest source of funding for basic research, its rate of investment in science has steadily declined over the years in inflation-adjusted dollars. Industry now dominates R&D in America, and the share of research funded by private philanthropy is also on the rise. These trends raise new challenges for setting and meeting national goals and objectives in an efficient and coordinated manner.

Finally, reversing these indicators of loss in US scientific leadership is nearly impossible without a public that trusts both science and scientists. According to a recent Pew Research survey, in the wake of the COVID-19 pandemic, fewer Americans say that science has had a mostly positive impact on society. This has major implications for how people understand the world, whether they are willing to support public funding for research, and if they will even follow the best science-based advice on climate change, pandemic preparations, and assuring energy, food, and water security.

To put US science on the best path for the future, I identified several major challenges that all of us in the research community should tackle. They include:

Improving K–12 education. As other nations increase their investment in R&D, fueling competition for international talent, we need to break our dependence on global STEM workers and cultivate our own domestic workforce. That means revamping and strengthening US STEM education. In particular, we should encourage children's innate curiosity by making science classrooms much more hands-on and experiential. We could also explore the potential of new technologies such as artificial intelligence to help overburdened teachers.

Creating a national research strategy. As industry and philanthropy become major funders of research alongside government, we should do a better job of coordinating research so that investments in science have maximum impact. The White House Office of Science and Technology Policy is working on such a strategy—which is a challenging task, given the many public and private entities involved in research and their differing goals and objectives. We need a balanced approach that also allows for the ability to take advantage of new and unexpected discoveries when they arise.

Reducing red tape. Decisionmakers should work to reduce the burden of regulations on faculty researchers, who spend 40% of their time outside the classroom on paperwork. The United States should lessen red tape that can be a barrier for foreign students who wish to study here, as well as for foreign graduates who wish to work stateside.

Bolstering university-industry partnerships. As industry continues to dominate R&D, we must find ways to strengthen engagement between industry and universities. I am especially concerned about research on AI, which is predominantly performed in the private sector at the moment, limiting opportunities to ensure that AI is applied for public good absent a profit motive. Rules of university engagement with industry should be modernized while remaining alert to possible conflicts of interest, which undermine public trust in science.

Strengthening international partnerships. Increasingly, big science projects such as CERN or the International Fusion Project depend upon the talent and resources of multiple countries. The United States should strengthen partnerships with other countries and invite their collaboration on US research priorities when appropriate, create well-communicated policies for where and when we should collaborate, and deploy procedures for evaluating the success of these collaborations.

Cultivating trust in science. Scientists should demonstrate that they are producing research that is credible, prudent, lacks bias, is self-correcting, and is beneficial—all qualities positively correlated with public support for science. Researchers at all levels should be rewarded for producing research that is excellent and trustworthy, and the research community should support excellence in communicating science to the public.

Navigating a course correction for science is no easy feat, given the complexity of our system and the number of players who need to get involved. To that end, we invited several prominent voices in the scientific community to respond to my address and share their perspectives on how we can make progress on these goals. I hope that everyone who cares about our research system finds a way to contribute. We must act now to ensure that science remains strong—for the benefit of all Americans.

Reversing these indicators of loss in US scientific leadership is nearly impossible without a public that trusts both science and scientists.

Marcia McNutt *is the president of the National Academy of Sciences.*

K–12 EDUCATION

Alexandra Fuentes

Though the United States has all the ingredients for leadership in science—world-class higher education institutions, strong industry and nonprofit sectors, philanthropic giving, and talented young people—not all US students have access to early or sustained learning experiences in the fields of science, technology, engineering, arts, and mathematics (STEAM) and computer science (CS) in prekindergarten through grade 12 (pK–12). To close the gaps, more coordination across the education ecosystem is necessary.

Every student should be able to access STEAM and CS learning experiences embedded in the school day. In elementary grades, this includes integrating content across disciplines and providing time for students to do hands-on engineering, coding, and computational thinking projects. In middle and high school, elective courses create pathways to college and careers. These classroom experiences can be enhanced when offered in conjunction with after-school and summer programs, family events, and work-based learning opportunities such as workplace tours, internships, and apprenticeships. Providing these layered STEAM and CS offerings demands more resources and coordination.

In Fairfax County, Virginia, where I work, state leadership and federal government investments are supporting student access to STEAM and CS. Virginia was one of the first states to establish K–12 CS standards and expand early access to CS. In a school division that serves nearly 183,000 students, grant funding from the Department of Defense Education Activity Military-Connected Local Educational Agencies for Academic and Support Programs has offered flexibility to fund central staff to support Code Up projects that are dramatically accelerating the integration of CS and STEAM into math instruction system wide.

Local employers, universities, and colleges have partnered with the school system to expand pK–12 opportunities that ignite student interest in STEAM and CS. For example, Capital One connects middle school students with mentors and hands-on learning in their Capital One Coders summer and after-school programs. The nonprofit Children's Science Center Lab has established a wide array of elementary, middle, and high school programs, including family science nights and internships for high schoolers in high-demand fields like cybersecurity. The Compose and Code program, funded by the National Science Foundation and led in partnership by researchers at George Mason University, Old Dominion University, and the University of Alabama, developed inclusive CS lessons that strengthen the computational thinking, coding, and writing skills of students with and without disabilities. George Mason University's Building the Quantum Workforce Project connects students with industry leaders and internships. And Northern Virginia Community College and the Northern Virginia Technology Council have partnered on the Aim High initiative to expand career experiences.

This strategic cross-sector coordination invests directly in the talent and ingenuity of young people, equipping pK–12 students in our region with the critical thinking and collaboration skills that fuel success. Providing STEAM and CS opportunities to all pK–12 students requires investment, but it offers a high return. One high school student in Fairfax County Public Schools merged topographic mapping practices with cell histology and artificial intelligence to invent an accurate method of diagnosing cancer—she now works in the field of AI. Her pathway to STEAM and CS began well before graduation.

__Alexandra Fuentes__ is senior manager of STEAM and Computer Science at Fairfax County Public Schools.

ADDRESSING RED TAPE

Matt Owens

The partnership between the federal government and academic research institutions has served the United States exceptionally well over the decades. Scientific and engineering discoveries and innovation have bolstered national security, health, and economic growth. Today, however, the necessary and well-intended—but inefficient and risk intolerant—regulation of this partnership impedes research, researchers and their institutions, and taxpayers' research investments.

The Council on Governmental Relations closely tracks, analyzes, documents, and comments on federal research regulations. In the past 10 years, the number of new and modified federal requirements and substantial updates to policies, business practices, and interpretations has grown by 181%. Many of these regulations address the same core issues, but in a disjointed manner across multiple agencies. This regulatory trajectory is unsustainable if the United States is to retain its leadership in science and innovation.

To cut red tape encumbering federally sponsored research, the following actions should be taken.

First, the most consequential action the federal government can take is to stand up the Research Policy Board authorized by the 21st Century Cures Act. No one federal agency can address the bloat and disaggregation of the current regulatory system. As recommended by a 2016 National Academies report, the Research Policy Board would be housed at the White House Office of Management and Budget (OMB)—where all federal regulations ultimately are approved—and serve as a primary policy forum for discussing ways to streamline and harmonize research regulations. In 2021, the nonpartisan Government Accountability Office reaffirmed the recommendation to OMB to establish this body.

Second, the White House Office of Science and Technology Policy should establish a position for associate director for the academic research enterprise, as recommended in the same National Academies report. This senior position would be a principal federal contact for the Research Policy Board, oversee and facilitate the general health of the research partnership, and work closely with OMB's Office of Information and Regulatory Affairs (OIRA) to manage overall regulatory burden. The position would also work with the OIRA administrator to issue an annual report on regulatory issues and actions affecting the partnership.

Third, regulators must calibrate regulation to risk. Research is never risk-free, and the most effective regulations are calibrated to address known and major anticipated risks without stultifying creativity and innovation. Excessive regulation occurs when risks are overstated and/or the government seeks earnestly to anticipate and eliminate *all* risk, no matter how minor or unforeseeable. This is an impossible and self-defeating approach that can divert resources needed to mitigate the most severe risks.

Together, these commonsense actions would establish a more effective regulatory oversight framework and help to rebalance and strengthen the research partnership that is vital to US science, innovation, and competitiveness.

***Matt Owens** is the president of the Council on Governmental Relations.*

BIDIRECTIONAL COLLABORATION

James Manyika

Advances in artificial intelligence are changing the tools available to conduct scientific research, reshaping the scale and scope of possible research questions, and accelerating the speed of discovery. Already, scientific discoveries enabled by AI are beginning to make a difference for people, expanding the potential to address pressing societal challenges like climate change and disease.

These advances are being powered by emerging transformations in university-industry relationships. In a conventional understanding of the way the US research enterprise works, the government funds basic research done by academics, and industry primarily focuses on funding and leading applied research. This view no longer represents the reality that most scientists in academia and industry experience. Industry is not just funding research—it is doing foundational research, often in deep collaboration with academic scientists. Additionally, traditional disciplinary distinctions are blurring, especially as the availability and use of data, computational AI, and machine learning tools become part of the foundational techniques advancing research. The new model for advancing the frontiers of science engages universities and industry in bidirectional scientific collaboration.

A recent landmark effort in connectomics to map a piece of the human brain to a level of detail never previously achieved shows how the traditional model of research is being upended. The breakthrough was made possible by a decade-long investment and deep collaboration between researchers at Google, the Howard Hughes Medical Institute, Harvard's Lichtman Lab, and others. The endeavor also highlights the multidisciplinary nature of cutting-edge research, as well as the importance of open collaboration tools—the full dataset, including AI-generated annotations for each cell, is publicly available on Neuroglancer.

Another example is Google DeepMind's AlphaFold, which led to breakthrough progress on the long-standing challenge of predicting protein structures and has predicted the structure and interactions of all of life's molecules including proteins, DNA, RNA, and ligands. This work was done in collaboration with academics, the European Molecular Biology Laboratory's European Bioinformatics Institute, and others. To date, the free, publicly available AlphaFold Server has been accessed by 2.2 million scientists in more than 190 countries—621,000 from the United States alone.

Such collaborations make more kinds of research more possible, but to build truly resilient industry-academic partnerships, and to develop a truly representative national approach to science, we must build research capacity where it doesn't currently exist. Right now, resources and research capacity are concentrated in a few companies and academic institutions. More investment in computing resources for academic researchers, as well as more shared and collaboratively used infrastructure are necessary. To have a truly national research strategy, it's essential that more people, institutions, and entities are able to participate.

***James Manyika** is Google's senior vice president of research, technology, and society.*

CULTIVATING TRUST

J. Marshall Shepherd

Cultivating trust in science requires commitment to the same basic principles that make strong leaders: authenticity, empathy, and logic. Though scholars are taught to be good researchers steeped in theory, methods, and scholarly reporting, I continually advocate for a more evolved approach in training the next generation of scientists, with the recognition that they will become the next generation of science leaders.

The scientific process values logic, providing frameworks for the constant inquiry, review, and advancement of knowledge. But the culture of science places less emphasis on the values of authenticity and empathy—both key to deepening an understanding of the social context of research.

My group's research on climate risk, for example, shows that socioeconomically disadvantaged groups such as the elderly, children under five, and communities of color are disproportionately vulnerable to floods, heat, and hurricane impacts. Those communities may also be skeptical of "ivory tower" pontification or focused on meeting their immediate needs, like putting food on the table.

The concept of "end-to-end" science incorporates the typical graduate training sequence of coursework, research, publishing, presenting, and so forth. However, it also includes media training, policy exposure, experiential learning, and coproduction of knowledge with stakeholders. By incorporating these elements in formal graduate education, we can start developing cohorts of empathetic scientists who see beyond the test tube, Doppler radar, or machine learning algorithm.

Even as the scientific establishment evolves to cultivate trust, there will still be bias, misinformation, disinformation, motivated reasoning, political agendas, and literacy challenges to overcome. But if scientists are not broadly engaging outside of laboratories or academic comfort zones, others will gladly rush in, like air to a vacuum, to fill the voids we leave behind.

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LEARNING TO LISTEN

Stephanie J. Diem

Whether virologists are trying to warn of an epidemic or roboticists are building new tools for workers, trust is the necessary ingredient in enabling scientific research to contribute to social transformation. If the public doesn't trust the methods, results, and intentions of science, it will not be interested in what we have to offer. And eventually, it will object to funding scientists and scientific education.

Public trust in clean energy technologies is essential to my work as a fusion engineer and plasma scientist, but over the course of my career I have often felt underprepared to engage in the important work of building such trust. The way scientists are trained and evaluated—often in academic siloes—can accentuate the importance of the theoretical at the expense of the actual, real-life impacts of research. And it usually skips over the significance of communicating science to the public, or even to other scientists.

Once I recognized this gap in my own scientific education, I set out to invest in my ability to engage in active listening, to better understand the values and points of view of others, and to apply that to telling the story of my work. The insights I've gained have transformed the way I communicate science and conduct my research. I am better able to inform my work with concerns and questions directly sourced from affected communities.

Today, in addition to running an experimental research group focused on developing new plasma initiation technology for future fusion energy systems, I also participate in interdisciplinary research that engages communities to understand how fusion energy can fit into the broader post-carbon energy portfolio. I do this work in concert with colleagues at the University of Wisconsin-Madison, the University of Michigan, and Arizona State University's Consortium for Science, Policy & Outcomes. Together, we are developing adaptations of the participatory technology assessment methodologies that have been used by NASA to determine how the public felt about asteroids. This process begins with 6–8 hour sessions where community members explore their values and how their hopes, concerns, and priorities might influence technology choices in fusion energy systems.

Bringing together diverse groups of people to find agreement or discover conflicting views in an accepting space is a rarity in this highly polarized time. And participants are excited their voices are being considered in the development of tomorrow's energy systems, in ways that may translate to tangible improvements to their lives and livelihoods.

Our hope is that by pursuing engagements like this, we can build trust and transparency during the process to design better, sustainable systems. When participants are asked to share their thoughts about the exercise, the responses are positive. One wrote, "I wish more researchers could do events like this to help the general public learn about their work. I'm sure there are so many interesting things being studied."

To me, this is why it is imperative that scientists have more opportunities to leave our siloes and learn to engage in real, two-way conversations with the public. To truly fulfill our mission of using science to create a better world, we must understand how the public wants that world to feel. Trust is a process that arises between people over time, and we must start to work on it now.

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