"Maintaining U.S. Leadership in Science and Technology"

Statement of

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before the

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Chairwoman Johnson, Ranking Member Lucas and members of the Committee, thank you for the opportunity to testify today. I am Marcia McNutt, president of the National Academy of Sciences. I am pleased to be here on behalf of the National Academies of Sciences, Engineering, and Medicine to discuss what I believe is one of the most important issues facing our nation — the health of the U.S. innovation enterprise and the implications for our long-term global competitiveness.

I will begin by providing a brief overview of the National Academies of Sciences, Engineering, and Medicine. We work on a remarkable range of issues that have science and evidence at their core, and we have long been a valuable resource for policymakers and the public.

More than 150 years ago, the National Academy of Sciences was created through a congressional charter signed by Abraham Lincoln to serve as an independent, authoritative body outside the government that could advise the nation on matters pertaining to science and technology. Under that original charter, the National Academy of Engineering (NAE) was founded in 1964 and the National Academy of Medicine (NAM, formerly the Institute of Medicine, IOM) in 1970.

Every year, approximately 6,000 Academies members and volunteers serve pro bono on our consensus study committees or convening activities. Our consensus study process is considered the gold standard of independent, nonpartisan, evidence-based advice. We do not advocate for specific policy positions. Rather, we enlist the best available expertise across disciplines to examine the evidence, reach consensus, and identify a path forward on some of society's most pressing challenges. In recognition of the fast-changing policy environment in which we all operate, we recently launched an Academies-wide effort to transform our processes, to ensure that our work is even more timely and relevant, without sacrificing the rigor and objectivity you rely upon.

Over the years, our advice informed the formation of the U.S. national park system and national highway system, the launch of the U.S.'s first Earth-orbiting satellite, and the mass-production of penicillin and other lifesaving drugs. More recently, our work strengthened the scientific consensus and public understanding of climate change, provided the blueprint for the Human Genome Project and precision medicine, bolstered the forensic science that underpins the U.S. criminal justice system, and provided a comprehensive estimate of the economic impacts of immigration into the U.S.

In 2018 alone, our advice covered issues as varied as modernizing the nation's interstate highways, securing the U.S. voting system, assessing the future of quantum computing, identifying the health effects of e-cigarettes, and eliminating lung diseases caused by exposure to coal mine dust. We proposed feasible paths for space exploration and the search for life in our universe, laid out a decadal strategy to enhance space-based observations of Earth and its complex systems, proposed measures to make prescription drugs more affordable, provided a research agenda for promising net emission technologies that remove carbon dioxide from the air, and recommended actions for fostering more openness and transparency in the research process. We also characterized the profound damage caused by sexual harassment — not only to the careers, health, and well-being of women who are harassed but also to the entire research enterprise. I am proud that our report helped this committee to take action on this front.

This year promises to be just as productive for the National Academies, and on issues such as modernizing the U.S. electric grid, defining the importance of reproducibility in research, helping public transportation adjust to disrupters such as Uber and Lyft, outlining the role of social and behavioral sciences in national security, and developing a blueprint for governance and research of climate engineering strategies. And our work extends far beyond our consensus studies; for example, our new Environmental Health Matters Initiative brings together expertise across the Academies to explore the science about environmental factors and human health, and our new Climate Communications Initiative provides policymakers with an unbiased resource for evaluating the science around global climate change. I invite you to review the attached list of 2018 reports specifically relevant to this Committee's jurisdiction.

Many of our studies originate in legislation; in the last Congress, for example, roughly 240 bills and resolutions were introduced either requiring a new Academies study or citing our previous work, and 26 new studies were ultimately mandated by law. During the 115th Congress alone, our members, volunteer experts, and staff participated in close to 200 congressional briefings. We are grateful that, for a non-governmental entity, this kind of presence on Capitol Hill may be unmatched. It reflects the incredible breadth of policy-relevant domains our vast network of experts can tackle, as well as the indispensable role that scientific inquiry and evidence can play in everyday life, beyond what one might consider to be conventional "science policy" issues.

A Strong U.S. Research Enterprise

Our work at the National Academies often centers on ensuring that advances in scientific knowledge, biomedical research, and technology are employed responsibly, and for the benefit of the nation. However, for those advances to occur in the first place, there must be strong and sustained investments in the people, facilities, and infrastructure that comprise our nation's innovation enterprise. Without this support, our nation will lose its competitive advantage in the global marketplace as the world's top talent will take their talent and ideas elsewhere, and the economic growth they have long generated here in the U.S. will follow. To be clear, this is not about creating jobs for scientists: this is an existential threat to America's greatness and the long-term welfare of our people.

More than 15 years ago, the National Academies released a landmark report called *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Future*, which stressed the importance of research for enhancing American competitiveness in a global economy. The report was instrumental to the development and adoption of the America COMPETES Act, the effort to increase basic research funding, and the creation of the Advanced Research Project Agency (ARPA-E) at the U.S. Department of Energy.

Now, in 2019, the messages from that report resonate more than ever. In an increasingly complex global economy, we simply cannot afford to let U.S. leadership in science slip away. In some cases, it already has. Given the often long lag time from research to applications, we may not realize the impacts of being behind until we are far behind, watching other nations reap the economic rewards and strategic advantages of early S&T investment.

The number of research journal publications by country is one metric to assess the vitality of U.S. research. It reflects a country's research capabilities and ability to generate new knowledge, as well as the potential pathways for that knowledge to technology innovation. According to the National Science Board's most recent Science and Engineering Indicators, the total number of

U.S. articles published began declining around 2014, despite consistent, steady growth in previous decades. At the same time, articles by Chinese researchers continued to increase significantly, ultimately surpassing the U.S. in 2016. This does vary considerably by field; the U.S. and European Union (EU) are still leading in publishing biomedical science articles, and China produces the most engineering articles.

Another measure is the relative output in knowledge- and technology-intensive industries. In the medium-high technology manufacturing fields such as vehicle parts, chemicals, and electrical equipment, China's output surpassed the U.S. in 2008 and the EU in 2011. But perhaps more concerning, in the high-technology industries such as aviation and telecom — where the U.S. has held a clear lead in the past — China is quickly gaining ground because of its substantial investments in research and advanced manufacturing, even as our and other nations' investments have leveled out.

These two metrics are good reminders of how innovation occurs across a spectrum — from knowledge generation through early stage basic research, to applied research and technology development, to deployment or commercial application. And at every step, we are facing increasingly intense competition from other countries, some of which may have more nimble and unconstrained innovation systems.

The U.S. research enterprise has traditionally been supported by a combination of government, university, private foundation and, of course, industry support. For the last few decades, private sector funding of research has indeed comprised an increasingly larger share of total R&D. But, by definition, industrial R&D is focused largely on near-term, more incremental improvements to existing commercial products and systems. In contrast, federally funded research generally generates crucial foundational knowledge for broader societal benefit, in ways that industry cannot or will not do alone. It is worth noting that those functions are not definitive and the process is not necessarily linear. Industry can certainly sponsor basic research, and federal funding can play an indispensable role in some later-stage technology innovation where the societal benefit is clear.

Federally funded research still comprises roughly a quarter of total R&D expenditures in the U.S. With so many competing demands on the federal budget, some question whether research still deserves high levels of continued support. Given the proven return on investment in publicly sponsored research and its role in generating and sustaining the STEM workforce, there can be no doubt: America is clearly served better through robust federal support of our research enterprise.

The STEM Talent Pipeline

Economic prosperity, national security, and advances in public health in the U.S. have for generations depended on a strong and diverse STEM talent pipeline. For decades, the world's top students flocked to U.S. universities to be educated, and the most capable of those have remained here to enrich our research enterprise and economy. Likewise, we did not have to worry about keeping our own domestic talent in the U.S. At one time we held a clear advantage because other countries lacked the resources or motivation to compete with the U.S. That is certainly not the case in 2019. We are in a global race to generate here and attract from abroad the best and brightest, who are looking for stable funding, better facilities, and the promise of lucrative careers.

There are troubling signs that the U.S. research workforce is getting older, U.S.-born students are not entering STEM fields in sufficient numbers, and foreign STEM students are no longer coming to the U.S. and staying to build lives and contribute to the economy as they did before.

The U.S. can maintain its competitive edge if we fix the incentives to improve career paths, attract a more diverse domestic scientific workforce, and keep our doors open to international talent.

Regardless of their country of origin, STEM graduates must see a successful future in their field if we hope to retain them. But far too often, they are discouraged by the high costs of education, decreasing success rates of grant proposals, and the long training phases of their careers. In our 2018 report *The Next Generation of Biomedical and Behavioral Sciences Researchers*, we note:

- The average age of first receipt of a NIH grant, the R01, has risen from 36 years old in 1980 to 43 years old in 2016.
- The share of biomedical Ph.D. recipients able to secure a tenure-track academic research position within six years has fallen from 55 percent in 1973 to 18 percent in 2009.
- The proportion of NIH research project grant dollars awarded to investigators under age 50 has declined from 54 percent in 1998 to 39 percent in 2014.
- While less than half of the current biomedical postdoc population are U.S. citizens, very few NIH postdoctoral and early career awards are available to non-U.S. citizens.

Furthermore, as identified in our 2018 report *Graduate STEM Education for the 21st Century*, the deeply technical graduate education system often does not adequately prepare students with a broad combination of the core competencies needed to lead in the modern workforce.

The cultural diversity of a nation's workforce is a key factor in its ability to innovate and compete in a global economy. We need to look beyond the traditional research universities in cultivating the pipeline of STEM talent, and the research community should better reflect the nation as a whole. One of our most recent reports, *Minority Serving Institutions: America's Underutilized Resource for Strengthening the STEM Workforce*, notes that the nation is still falling far short in attracting and retaining students of color to STEM fields. With over 700 MSIs in the U.S., and an ever-expanding range of STEM-related fields, this is talent that we obviously cannot afford to squander. I invite you to review these reports for a comprehensive look at the issues and lists of actions all stakeholders can take to improve the system.

Any discussion about U.S. S&T leadership must acknowledge the critical role that non-U.S. students and workers have to play in our competitiveness. Though U.S. universities remain the destination of choice for international talent, for the first time the numbers have fallen in recent years. According to the last Science and Engineering Indicators, international science and engineering graduate student enrollments dropped 6 percent from 2016 to 2017. Though this is a recent phenomenon, the indications are that the trend may continue. The most recent data from the Council on Graduate Schools indicate a continued decline in temporary visa holder enrollment in 2018. The trends vary across fields, with some of the sharpest drops in engineering and physical and earth sciences. For example, according to a recent survey by the American Physical Society, international applications to U.S. physics Ph.D. programs declined an average of 12 percent in 2018. At the same time, our competitor institutions in Canada, Germany, Australia, and elsewhere saw significant increases. Unfortunately, this comes at a time when both funding for U.S. public universities and entry of U.S-born students into STEM fields have fallen.

Our report *Graduate STEM Education for the 21st Century* states that foreign graduate students who remain here after earning their degrees benefit the U.S. in myriad ways, including contributing to an increase of more than $39 billion to our economy in 2016. Stay rates are highest in fields where temporary visa holders are most prevalent: engineering, physical sciences, and life sciences.

We must also recognize the ever-shifting landscape of risks and the fact that our competitors will continually seek to exploit our open academic research system for their strategic security and economic advantages. Healthy vigilance in this regard will require the close coordination of our national security, law enforcement, and research funding agencies, as well as academic and other research performing institutions, to ensure that we do not underestimate the risks or undermine the deep benefits foreign students and international cooperation provide for our nation. With foreign students making up roughly one-third of science and engineering graduate students in the U.S. — and the clear majority in some S&T fields — we must very carefully consider the long-term impacts of policy measures that discourage or ban non-U.S. citizens from contributing to our innovation system.

International Cooperation

Across a range of S&T domains, international competition is intense, and with our allies and adversaries alike. Fortunately, the global scientific community has a long tradition of transcending political and economic differences to coordinate or consult on major scientific challenges for the health and welfare of the world, and to push the frontiers of knowledge beyond what one country can do on its own. Examples today can be seen in the International Space Station, the ITER nuclear fusion reactor, the Large Hadron Collider at CERN, Arctic and Antarctic research, and nonproliferation of nuclear weapons. International coordination may well play a critical role in emerging and highly competitive fields with broad societal impacts, such as artificial intelligence, quantum computing, robotics, synthetic biology, nanotechnology, and even lunar exploration.

Fostering these exchanges is more important than ever. Science and engineering are increasingly international endeavors, and are being rapidly transformed by globalization, interdisciplinary team-driven research, and information technology. International collaboration and cooperation are also important for informing the responsible conduct of science, avoiding and identifying fraud and bias, and communicating findings with the public. This is especially critical for fast-moving, cutting-edge areas of research that have global implications. For instance, Human genome editing offers great promise around the world in treating genetic diseases, but it is imperative that we examine the many scientific, ethical, and governance issues raised by powerful new genome editing tools such as CRISPR-Cas9. Of particular concern are heritable genome edits that might be passed down to future generations.

The National Academy of Sciences and the National Academy of Medicine have organized two international summits and a consensus study to explore the complex issues surrounding human genome editing. The Second International Summit on Human Genome Editing — co-hosted last year with the Academy of Sciences of Hong Kong and the Royal Society of the U.K. — brought together in Hong Kong more than 500 researchers, ethicists, clinicians, patient groups, and others from around the world to discuss the issues, and was viewed online in approximately 190 nations

The summit was already generating international headlines when a Chinese researcher — in violation of long established scientific principles and norms — claimed to have edited early embryos that resulted in the birth of twins. The news drew widespread condemnation, but it also served to heighten the urgency for more in-depth analysis of the complex scientific, ethical, and societal issues that surround heritable genome editing. This year, the NAS and NAM are partnering with the Royal Society and other academies around the world to form an international commission tasked with developing stringent criteria and standards to guide responsible decisions about heritable human genome editing research and applications.

Scientific cooperation is just as important as competition if we hope to address large-scale global issues such as human genome editing. However, if the U.S. loses its edge in science and technology, opportunities for international collaboration will also suffer.

Conclusion

As we have for more than 150 years, the National Academies stand ready to serve the nation and the world on these and many other issues. We can provide a science and evidence base as you assess the appropriate functions of agencies and programs, set priorities for research funding, and deliberate on how to strike the right balance between public and private contributions. We can provide guidance for decisions about making the most of federal investments in the research enterprise, including the STEM talent pipeline, facilities, and infrastructure. However, we must all keep in mind that other nations are not hesitating to debate many of the issues we face. They are examining every metric of competitiveness, and looking years ahead to make large investments in their own expanding research enterprise.

Yes, the U.S. has ceded leadership in some areas, but we remain at the top in many others. As Members of the U.S. House Committee on Science, Space, and Technology, you have the opportunity to make policies and conduct oversight that ensures we do not ever surrender our global leadership in science and technology. The stakes are simply too high for U.S. economic competitiveness, national security, and the health and well-being of our citizens. Together, we must support and maintain a strong, robust U.S. research enterprise.

Additional Resources (with links)

- National Science Board – *Science and Engineering Indicators 2018*
- NASEM Study - *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Future* (2007)
- NASEM Study - *The Next Generation of Biomedical and Behavioral Sciences Researchers: Breaking Through* (2018)
- NASEM Study - *Graduate STEM Education for the 21st Century* (2018)
- NASEM Study - *Minority Serving Institutions: America's Underutilized Resource for Strengthening the STEM Workforce* (2019)
- Council of Graduate Schools – *International Graduate Applications and Enrollment: Fall 2018*
- American Physical Society – *International Applicants Survey Results* (2018)
- The Interacademy Partnership – *Doing Global Science: A Guide to Responsible Conduct in the Global Research Enterprise* (2016)
- NASEM Initiative – *Human Genome Editing*