Biennial Report to Congress on International Science & Technology Cooperation

A Report by the

SUBCOMMITTEE ON INTERNATIONAL SCIENCE & TECHNOLOGY COORDINATION

of the

NATIONAL SCIENCE AND TECHNOLOGY COUNCIL

September 2022

About the Office of Science and Technology Policy

The Office of Science and Technology Policy (OSTP) was established by the National Science and Technology Policy, Organization, and Priorities Act of 1976 to provide the President and others within the Executive Office of the President with advice on the scientific, engineering, and technological aspects of the economy, security, health, foreign relations, the environment, and technology, among other topics. OSTP leads interagency science and technology policy coordination efforts, assists the Office of Management and Budget with an annual review and analysis of Federal research and development in budgets, and serves as a source of scientific and technological analysis and judgment for the President with respect to major policies, plans, and programs of the Federal Government. More information is available at https://www.whitehouse.gov/ostp.

About the National Science and Technology Council

The National Science and Technology Council (NSTC) is the principal means by which the Executive Branch coordinates science and technology policy across the diverse entities that make up the Federal research and development enterprise. A primary objective of the NSTC is to ensure science and technology policy decisions and programs are consistent with the President's stated goals. The NSTC prepares research and development strategies that are coordinated across Federal agencies aimed at accomplishing multiple national goals. The work of the NSTC is organized under committees that oversee subcommittees and working groups focused on different aspects of science and technology. More information is available at https://www.whitehouse.gov/ostp/nstc.

About the Subcommittee on International Science and Technology Coordination

The purpose of the Subcommittee on International Science and Technology Coordination (ISTC) is to enhance coordination of the Federal agencies' international science and technology cooperation and partnerships. The Subcommittee addresses long-term strategic engagement goals, policy issues related to high-value international collaboration, and short-term country- and issue-specific priorities. The Subcommittee serves as a forum to discuss Administration priorities and agency-level activities in support of those priorities.

About this Document

The American Innovation and Competitiveness Act[1] directs the Director of OSTP to submit a biennial report on international science and technology (S&T) cooperation efforts to the Senate Committees on Commerce, Science, and Transportation and Foreign Relations and the House Committees on Science, Space, and Technology and Foreign Affairs. The first biennial report from the ISTC Subcommittee in 2020 described ongoing S&T coordination and collaboration efforts with Israel, the Republic of Korea and the United Kingdom, and provided examples of S&T collaboration in the areas of big data systems and science, infectious disease and pandemic research, and ocean observation systems. This second report provides an overview of the United States' position in the global research and development (R&D) landscape and identifies areas where the United States remains a global S&T leader and areas where the United States is losing competitiveness. The report also includes recommendations to firmly establish U.S. leadership in international S&T engagement.

Copyright Information

[1] American Innovation and Competitiveness Act (Pub. L. 114-389) §208(e), 42 U.S.C. §6625(e) (Note: Sec. 208 of Pub. L. 114-389 is also known as the International Science and Technology Cooperation Act of 2016).

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Table of Contents

Abbreviations and Acronyms

AAAS	American Association for the Advancement of Science
AI	Artificial Intelligence
AIM	Agriculture Innovation Mission (for Climate)
ALMA	Atacama Large Millimeter/submillimeter Array
AMACAD	American Academy of Arts & Sciences
BHP	Botswana-Harvard AIDS Institute Partnership
CCP	Chinese Communist Party
CERN	European Organization for Nuclear Research
CRISPR	Clustered regularly interspaced short palindromic repeats
CSET	Center for Security and Emerging Technology
CTS	Connected Technology Solutions
DEIA	Diversity, equity, inclusion, and accessibility
DHS	Department of Homeland Security
DIV	Development Innovation Ventures Program
DoD	Department of Defense
DOE	Department of Energy
DOI	Department of the Interior
DOS	Department of State
DOT	Department of Transportation
DUNE	Deep Underground Neutrino Experiment
ECLAC	Economic Commission for Latin America and the Caribbean
ELI	Extreme Light Infrastructure
EMN	European Migration Network
EPA	Environmental Protection Agency
EPSCoR	Established Program to Stimulate Competitive Research
ESF	Embassy Science Fellows
ESO	European Southern Observatory
ESTH	Environmental, scientific, and public health
EU	European Union
Euratom	European Atomic Energy Community
GDP	gross domestic product
GIST	Global Innovation through Science and Technology
HBCUs	Historically Black Colleges and Universities
HHS	Department of Health and Human Services
IFAFRI	International Forum to Advance First Responder Innovation
INA	Immigration and Nationality Act

ISS	International Space Station
ISTC	Subcommittee on International Science and Technology Coordination
ITER	International Thermonuclear Experimental Reactor
KTI	knowledge- and technology-intensive industries
LBNF	Long-Baseline Neutrino Facility
LMIC	Low- or middle-income country
MERC	Middle East Regional Cooperation
MSIs	Minority-serving institutions
MWDI	Mekong Water Data Initiative
MOU	Memoranda of understanding
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NIH	National Institutes of Health
NIST	National Institute of Standards and Technology
NMIs	National metrology institutes
NOAA	National Oceanic and Atmospheric Administration
NSB	National Science Board
NSF	National Science Foundation
NSPM-33	National Security Presidential Memorandum 33
NSTC	National Science and Technology Council
OECD	Organisation for Economic Cooperation and Development
OMB	Office of Management and Budget
OPT	Optional practical training
OSTP	Office of Science and Technology Policy
PEER	Partnerships for Enhanced Engagement in Research program
PRC	People's Republic of China
R&D	Research and development
S&E	Science and engineering
S&T	Science and technology
SESAME	Synchrotron-light for Experimental Science and Applications in the Middle East
SFI	Science Foundation Ireland
SI	Smithsonian Institution
SKA	Square Kilometer Array
SMART	Science, Mathematics, and Research for Transformation Scholarship-for-Service program
STA	Science and technology agreement
STEM	Science, technology, engineering, and math
TWAS	The World Academy of Sciences

U.K.	United Kingdom
U.S.	United States
USAID	United States Agency for International Development
UNESCO	United Nations Educational, Scientific and Cultural Organization
USDA	United States Department of Agriculture
USD(R&E)	Under Secretary of Defense for Research and Engineering
USGS	United States Geological Survey
USPTO	United States Patent and Trademark Office

Executive Summary

International collaboration on science and technology (S&T) enables the scientific enterprise to push the boundaries of human understanding, minimize the impacts of transnational disasters, leverage expertise and capacity beyond national borders, and bridge communities. S&T has a central role in the current phase of geopolitical competition, in which national S&T capacity is widely recognized as a pivotal factor in each country's ability to adapt to changing circumstances as well as a tool to affect the international landscape. To remain at the forefront of leading the way to address national, transnational, and global challenges and to succeed in this phase of global competition, the United States must be sufficiently agile and have both the diplomatic and programmatic capacity to meet an increasingly challenging and interconnected international environment.

Origins of this Report

When former Secretary of State Madeline Albright initiated changes that strengthened the State Department's S&T diplomacy apparatuses in 2000 in a policy statement titled "Science Diplomacy: Strengthening State for the 21st Century," she acknowledged that strengthening the Nation's S&T diplomacy capabilities would be a long-term effort that could require prioritizing new personnel and resources. This report is a continuation of that effort and identifies areas of excellence and gaps in the U.S. approach, along with recommendations to ensure that the United States can support global needs while also promoting American values and advancing American economic and national security objectives. Many of these recommendations are not new, having originated in two National Research Council reports, *The Pervasive Role of Science, Technology, and Health in Diplomacy* (1999) and *Diplomacy for the 21st Century: Embedding a Culture of Science and Technology Throughout the Department of State* (2015), and the recent work of the American Academy of Arts and Sciences "Challenges for International Science Partnerships" project. This report emphasizes recommendations reflecting the collective experience of international personnel across the Federal research enterprise, and underscores that the issues raised at the turn of the century, and others, continue to be pressing and so merit ongoing U.S. government consideration and action.

Areas of Excellence in the U.S. Approach to International S&T

1. The United States remains a global leader in many areas of S&T. Competitors are catching up.
2. Investigator-driven international collaborations are working: U.S. government agencies actively collaborate with international partners, and are highly effective at supporting investigator and mission-driven research both domestically and internationally.
3. The United States sets and informs standards for global science: U.S. experts inform and lead international discussions on technology, standards, ethics, and the responsible practice of science.
4. The United States attracts and retains science, technology, engineering, and mathematics (STEM) talent, but can do more to ensure that international talent chooses to come to the United States and remain.
5. The United States can achieve diplomatic and national security goals with international S&T engagement.

Gaps in the U.S. Approach to International S&T Engagement

1. The United States is missing out on both short- and long-term strategic opportunities to engage internationally and is being left behind as a result. Countries and international organizations able

to engage globally on S&T issues, including through funding for international initiatives, will have a strategic advantage.

2. The United States spearheads a limited number of ambitious, large-scale international S&T research collaborations for specific topics. Foreign governments are increasingly supportive of multinational research consortia, and they are willing to spend billions of dollars to participate; the United States has no similar science diplomacy initiatives.
3. Mission-driven scientific activity and foreign policy/national security interests must be more coordinated and balanced among Federal agencies to minimize siloes among development, national security, and research priorities.
4. The United States is likely underperforming in achieving Diversity, Equity, Inclusion, and Accessibility (DEIA) goals in international S&T, which may be having a negative impact on U.S. competitiveness. The broader U.S. population is not well-represented in international scientific programs and exchanges at all levels, and likely is not experiencing equitable participation in international research collaborations.
5. The legal requirement that F-1 or J-1 visa holders change their visa class or immigration status at the end of their studies if they wish to remain in the United States may serve to exclude foreign talent.
6. Federal science agencies do not prioritize staffing for international collaborations and the U.S. government could do more to retain scientists who are trained in diplomacy.
7. Science and Technology Agreements (STAs) are good tools for research-performing agencies to accelerate collaborative activities, but they may raise funding or bilateral engagement expectations that the United States is unable to fulfill.

Recommendations

1. Explore mechanisms to support students from lower and middle-income countries (LMICs) to engage with the U.S. S&T enterprise.
2. Conduct research to understand why STEM talent leaves the United States or chooses to go to other countries, including examining the entire innovation pipeline to identify research, development, regulatory, statutory, capacity, and infrastructure challenges to STEM talent recruitment and retention.
3. Expand the use and scope of Embassy Science Fellows (ESP) and other exchange programs, as well as long-term detail opportunities between government agencies in international S&T. Work to ensure that these opportunities are open to all levels of knowledge and experience to break down siloes and provide cross-agency integration at various professional levels. Identify and remove barriers for participation in these programs to better promote principles of DEIA and ensure that the international S&T workforce better reflects the U.S. population and U.S. scientific community.
4. Explore transnational exchanges between U.S. and foreign technical agencies to increase opportunities for collaboration with close partners while addressing barriers to cooperation.
5. Strengthen the U.S. research and innovation environment to enable U.S. global S&T leadership, including working through multilateral fora, increasing opportunities for participation by and partnerships with LMICs, and motivating private sector research and development (R&D) and STEM professionals to remain in the United States.

6. Consider the development of flexible and longer-term approaches to funding international collaborative science to compete with other countries' longer-term research funding initiatives, such as those enabled by the People's Republic of China's (PRC's) five-year plans or the European Union's (EU's) seven-year multiyear financial framework.
7. Explore the creation of a flexible mechanism within the Department of State (DOS) to support joint S&T goals, research, and innovation with foreign partners. Projects and initiatives could include consortia support and support for international facilities that are of strategic scientific, national security, and/or foreign policy interest to the United States.
8. Explore the creation of a mechanism under which assistance for S&T collaboration can be provided to international partners who otherwise lack scientific capacity. Partners may include nations that do not qualify for development assistance and/or lack existing STEM capacity to participate in research collaborations intended to be mutually beneficial.
9. Expand detail opportunities between international offices in science and technical agencies to allow Federal experts to better familiarize themselves with international S&T practices and networks in other parts of the U.S. government.
10. Encourage amplification of existing international S&T collaboration efforts through public diplomacy, media outreach, and sustained people-to-people-level engagement.
11. Explore mechanisms to support exchange visitor programs with Historically Black Colleges and Universities (HBCUs, other Minority-Serving Institutions (MSIs), and institutions in Established Program to Stimulate Competitive Research (EPSCoR) jurisdictions, as well as training and development programs at all educational levels that may increase the capacity of interested institutions to more readily engage with international partners.
12. Explore how researchers in both STEM and non-STEM fields at HBCUs, other MSIs, and institutions in EPSCoR jurisdictions are participating in international S&T collaborations, including as reflected in co-authored publications. Assess whether and how international engagement can act as a career accelerator for researchers and students from underrepresented groups and if additional mechanisms may be needed to positively impact representation in international S&T settings.
13. Critically review existing job series and consider new series that would allow the recruitment of technical professionals within agencies to support S&T diplomacy and enhance the government's ability to recruit skilled and specialized representation for highly technical international activities, including standards-setting bodies and international technical working groups.
14. Explore the creation of mechanisms within the U.S. government that mobilize and train Federal scientists to communicate effectively to non-scientist decision makers within the U.S. government and abroad.
15. Consider providing incentives and training opportunities to experts who contribute to international standards-setting bodies and other relevant working groups to ensure that the appropriate technical experts are active contributors to these discussions.
16. Assess current STAs for relevancy and gaps with a view to addressing with foreign partners as and when appropriate. Evaluate mechanisms for the United States to increase data and facility access, scientific exchange, and visa or customs and border flexibilities for visitors from private sector and academic institutions in connection with STAs or related agreements.

Introduction

International S&T cooperation has been a pillar of U.S. foreign policy since the end of World War II and has helped build an international order predicated on mutual safety and prosperity. Working transparently on shared research agendas with international partners helps the United States rapidly characterize complex global issues and identify solutions, innovate and adopt new technologies, and support meritocracy and academic freedom. Global technology competition, including for talent, knowledge and markets, is predicted to increase in the current decade and beyond,[2] and the United States must be able to respond.

Engaging in S&T has economic, political, societal, scientific, national security, development, and diplomatic benefits, both domestically and internationally. Addressing complex scientific questions or crosscutting multi-sectoral challenges that affect all Americans – such as food insecurity, climate change, or a global pandemic – requires a robust domestic S&T infrastructure. International collaboration helps enable the United States to compete economically, defend national interests and national security interests, and maintain resiliency to meet increasingly complex challenges that transcend national boundaries. These relationships serve multiple aims, such as to improve economic and security relationships between countries, help build national capacity in other countries, or address global challenges that require international collaboration. When cooperating, nations can pool resources and expertise, maximizing their efforts so that research can be done at larger scales and for longer time periods to address complex problems.

Cooperation also brings together differing viewpoints that can unlock discoveries and lead to the development of more effective solutions. U.S. S&T leadership encourages best practices to be implemented worldwide and helps to shape global perceptions of U.S. expertise, which can foster U.S. scientists being sought after internationally for standards and guidelines development as well as for future international collaboration. On an individual basis, collaboration gives researchers an opportunity to learn beyond their nation's territory, address urgent global challenges that are relevant to the United States, and engage with scientists who may approach scientific questions differently. These opportunities provide researchers with experience and perspectives that increase their research quality, which can then further attract foreign researchers to come to the United States.

Effective international science engagement builds and deepens connections between U.S. and foreign S&T communities. By convening national and international experts, these efforts can invigorate S&T agreements and collaboration as well as improve the dissemination of data. International science engagement deepens bonds with other countries, which can help to counter the influence of countries like the PRC or Russian Federation, on the global S&T ecosystem in support of the U.S. domestic S&T enterprise. Diplomacy can address international S&T impediments, such as data sharing and research permits, and facilitate cooperation. Along with creating and strengthening bonds with other nations, science diplomacy can also offer opportunities for promoting a healthy science and technological ecosystem, and may, when appropriate, help to bring adversaries together on S&T topics that are of mutual benefit in spite of geopolitical tensions.

The aim of this biennial report is to provide a high-level view of where the United States stands with respect to international S&T. The "Areas of Excellence in the U.S. Approach to International S&T" section presents the ISTC Subcommittee findings and recommendations for areas in which the United

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[2] National Intelligence Council. 2021. *Global Trends 2040: A More Contested World.* Washington, D.C.: National Intelligence Council. https://www.dni.gov/files/ODNI/documents/assessments/GlobalTrends_2040.pdf.

States is succeeding and providing global leadership, both internationally and as a result of the domestic U.S. S&T enterprise. The "Gaps in the U.S. Approach to International S&T Engagement" section presents findings and recommendations for areas in which the United States risks falling behind. These recommendations, if prioritized, may require either Executive or Legislative action. The final section, "Looking Forward", summarizes the U.S. position if these recommendations are put into action.

Areas of Excellence in the U.S. Approach to International S&T

The United States currently excels in S&T domestically and internationally in several areas described within the five findings below: annual overall R&D investment, researcher-driven efforts, setting global standards and norms, attracting and retaining STEM talent, and achieving diplomatic and national security goals with international S&T engagement. In order to maintain excellence in S&T, the United States must be able to flexibly seek out, scout, and fund opportunities when and where they emerge not only for the advancement of American S&T competitiveness, but also for maintaining American influence abroad.

Finding 1: The United States remains a global leader in many areas of S&T. Competitors are catching up.

The United States leads in S&T in terms of funding and research metrics, although there are recent indications U.S. leadership has eroded or disappeared in measures such as highly-cited research publications.[3] In other metrics, such as the economic output of knowledge- and technology-intensive industries (KTI),[4] the United States now trails the PRC.[5]

Historically, the United States has been the global leader in international S&T investment, contributing almost 70% of global R&D investment in 1960.[6] The United States has retained this leadership in recent decades: in 2000, the United States spent more than double on R&D compared to the second-highest spending nation.[7] However, this gap is narrowing. Estimated values for 2019 global R&D expenditures show that the United States contributed 27% ($658 billion), while the PRC contributed 22% ($526 billion), and Japan contributed the third-largest amount (7%; $173 billion).[8]

[3] While experts may disagree on the metrics or the completeness of the underlying data, decades-long trends suggest that competition to generate new knowledge as a precursor to economic and society leadership is changing. *Science*. 2022. "China rises to the first place in most cited papers." https://www.science.org/content/article/china-rises-first-place-most-cited-papers.

[4] KTI are "industries classified by the Organisation for Economic Co-operation and Development (OECD) as high R&D intensive and medium-high R&D intensive industries. The OECD defines R&D intensity as the ratio of an industry's business R&D expenditures to its value added." National Science Board. 2022. "Science and Engineering Indicators, Production and Trade of Knowledge- and Technology-Intensive Industries, Glossary." https://ncses.nsf.gov/pubs/nsb20226/glossary#definitions.

[5] National Science Board. 2022. "Science and Engineering Indicators, Production and Trade of Knowledge-Intensive Industries." https://ncses.nsf.gov/pubs/nsb20226/global-trade-in-knowledge-and-technology-intensive-output.

[6] Office of Technology Policy, U.S. Department of Commerce. 1997. *The Global Context for U.S. Technology Policy*. https://usa.usembassy.de/etexts/tech/nas.pdf.

[7] The United States contributed 37.1% of global R&D expenditure in 2000 and 29% in expenditure in 2010. National Science Board. 2022. "The State of U.S. Science and Engineering 2022, U.S. and Global Research and Development." https://ncses.nsf.gov/pubs/nsb20221/u-s-and-global-research-and-development.

[8] National Science Board. 2022. "The State of U.S. Science and Engineering 2022, U.S. and Global Research and Development." https://ncses.nsf.gov/pubs/nsb20221/u-s-and-global-research-and-development.

This decrease in the U.S. share of expenditures is not due to decreased overall spending, as U.S. annual spending generally increased from 2000 to 2019,[9] but because the PRC's R&D investments have grown by double-digit percentages between 2000-2013 and 2017-2019. In contrast, the United States never experienced double-digit growth in annual R&D investment between 2000 and 2019. Prior to 2010, the PRC's investment in R&D was less than half that of United States, but the PRC is closing the gap, for their investment in R&D is still growing at a faster rate than that of the United States.[10] This narrowing gap is a concern because the PRC and other competitors do not follow the norms of standard regional and global order, and in some cases, intentionally compete with the intent of overtaking the United States in civil and military capabilities. Beginning in 2017, publications from China received citations above the number expected, given the number of articles produced.[11] In 2011, the PRC surpassed the United States to become the world's largest producer of KTI manufacturing output, and the PRC has been the driving force behind the rapid increase of this output for many KTI industries over the past decade.[12]

The largest contributor to R&D investment in the United States in the 21st century is the private sector, which contributes between 61% and 72% of total U.S. R&D spending annually. Federal investment in R&D over the same time period has only ranged between 20% and 31%. In the past decade, private-sector R&D investment has grown by 95% compared to 6% growth in Federal Government investment over the same period.[13] This Federal investment across S&T sectors has not been consistent; for example, U.S. public sector spending on agricultural research decreased during this time and is lower than public agricultural research spending in the Brazil, India, and the PRC.[14]

The domestic S&T enterprise provides the foundation for U.S. international S&T leadership. A recent analysis of data available through 2018 indicates the United States leads the world in high-impact research publications,[15] and also led the world in this area in 2000 and 2010.[16] This trend continues in critical research areas: a recent analysis of 2020 research publications related to the COVID-19 pandemic showed that the United States played a central role in international research collaboration

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[9] U.S. spending increased from $269.5 billion in 2000 to $410.1 billion in 2010 and $657.5 billion in 2019. National Science Board. 2022. "The State of US Science and Engineering 2022, U.S. and Global Research and Development." https://ncses.nsf.gov/pubs/nsb20221/u-s-and-global-research-and-development.

[10] From 2015 to 2019, the PRC's investment grew by 44% compared to 33% growth in U.S. investment over the same period. The PRC's growth has slowed slightly, but as of 2019 still exceeds US growth rates. Analysis of data from the National Science Board. 2022. "The State of U.S. Science and Engineering 2022: U.S. and Global Research and Development." https://ncses.nsf.gov/pubs/nsb20221/u-s-and-global-research-and-development.

[11] See National Science Board. 2022. "The State of U.S. Science and Engineering 2022, U.S. and Global Science and Technology Capabilities: Knowledge- and Technology-Intensive Industry Output." https://ncses.nsf.gov/pubs/nsb20221/u-s-and-global-science-and-technology-capabilities.

[12] See National Science Board. 2022. "The State of U.S. Science and Engineering 2022, U.S. and Global Science and Technology Capabilities." https://ncses.nsf.gov/pubs/nsb20221/u-s-and-global-science-and-technology-capabilities.

[13] Analysis of data from the National Science Board. 2022. "The State of US Science and Engineering 2022, U.S. and Global Research and Development." https://ncses.nsf.gov/pubs/nsb20221/u-s-and-global-research-and-development.

[14] Nelson, Kelly P. and Keith Fuglie. 2022. "Investment in Public Agricultural Research and Development in the United States Has Fallen by One-third Over the Past Two Decades." *Amber Waves*. USDA Agricultural Research Service. Last modified June 6, 2022. https://www.ers.usda.gov/amber-waves/2022/june/investment-in-u-s-public-agricultural-research-and-development-has-fallen-by-a-third-over-past-two-decades-lags-major-trade-competitors/.

[15] The National Science Board uses the metric "article citations", which represents a country's share of the top 1% most-cited science and engineering (S&E) publications divided by the country's share of all S&E publications. National Science Board. 2022. "The State of U.S. Science and Engineering 2022, U.S. and Global Science and Technology Capabilities". https://ncses.nsf.gov/pubs/nsb20221/u-s-and-global-science-and-technology-capabilities#research-publications.

[16] In 2018, the United States had a 1.82 cited article impact score, compared to 1.28 for the EU-27 countries and 1.18 for the PRC. National Science Board. 2022. "The State of U.S. Science and Engineering 2022, U.S. and Global Science and Technology Capabilities. https://ncses.nsf.gov/pubs/nsb20221/u-s-and-global-science-and-technology-capabilities.

on this topic.[17] However, as of 2018, the EU and PRC have joined the United States in the category of highly-cited countries and economies for science and engineering publications.[18] Another recent study analyzed highly-cited publications from 2018 to 2020; while it is not definitive in absolute terms, it does support the continued decades-long trend of U.S. leadership eroding or disappearing and the PRC advancing in this category.[19]

Finding 2: Investigator-driven collaborations are working.

U.S. government agencies support a world-leading domestic S&T enterprise, actively collaborate with international partners, and are highly effective at supporting investigator and mission-driven research both domestically and internationally.

The U.S. government supports and engages in specific, large-scale collaborations that drive and advance S&T across international partner governments and academia, often in collaboration with the private sector. International S&T engagement provides an avenue for productive relationships with international counterparts and helps increase Federal agencies' influence, especially in multilateral organizations that can potentially advance U.S. priorities on areas such as climate change, food security, data sharing, and emerging technologies. For example, the European Organization for Nuclear Research (CERN) was established in 1956 and provided opportunities for U.S scientists and engineers to collaborate with adversarial nations during the Cold War.[20] This partnership continued after the fall of the Soviet Union, with the United States and Russia working together to launch the International Space Station (ISS) in the 1990s.[21] The United States is an observer at CERN and currently forms the largest user group for its research facilities.[22] NASA routinely spearheads ambitious, large-scale international S&T research collaborations, including robotic space exploration missions such as the Mars 2020 Perseverance rover and James Webb Space Telescope, as well as human spaceflight missions such as the ISS, Gateway, and Artemis programs. Another past success is the Human Genome Project, an effort initiated by the U.S. government that later included four other countries. The results from this work were made public and have served as a reference for many biomedical projects worldwide.[23] The Atacama Large Millimeter/submillimeter Array, which is composed of 66 telescopes located in several

[17] See Figure A in: National Science Board. 2022. "The State of U.S. Science and Engineering 2022, U.S. and Global Research and Development, Disruptions and Breakthroughs in S&E during the COVID-19 Pandemic." https://ncses.nsf.gov/pubs/nsb20221/u-s-and-global-research-and-development.

[18] See National Science Board. 2022. "The State of U.S. Science and Engineering 2022: U.S. and Global Science and Technology Capabilities: Research Publications." https://ncses.nsf.gov/pubs/nsb20221/u-s-and-global-science-and-technology-capabilities.

[19] *Science*. 2022. "China rises to the first place in most cited papers." https://www.science.org/content/article/china-rises-first-place-most-cited-papers.

[20] CERN members consist of 23 European nations and Israel. American Academy of Arts & Sciences (AMACAD). 2020. *America and the Future of Science*. https://www.amacad.org/sites/default/files/publication/downloads/2020-CISP-Report-1.pdf.

[21] The ISS partnership started in 1998 and brings together scientists, engineers, and researchers from around the world. It is currently a partnership among the U.S., Russia, Japan, the EU, and Canada. See: NASA. n.d. "International Space Station." https://www.nasa.gov/mission_pages/station/structure/elements/partners_agreement.html.

[22] U.S. researchers form the largest user community at CERN, numbering 2100 individuals from 31 U.S. institutions. American Academy of Arts & Sciences (AMACAD). 2020. *America and the Future of Science*. https://www.amacad.org/sites/default/files/publication/downloads/2020-CISP-Report-1.pdf.

[23] American Academy of Arts & Sciences. 2021a. *Bold Ambition: International Large-Scale Science.* https://www.amacad.org/publication/international-large-scale-science.

countries, is partly funded by the United States.[24] A coalition of 200 astronomers from 13 international research centers used the sum of their resources to develop a first-of-its-kind global research apparatus that produced the first image of a black hole and its shadow in 2019.[25] The United States is also supporting the Long-Baseline Neutrino Facility (LBNF) and the Deep Underground Neutrino Experiment (DUNE) at the Fermi National Accelerator Laboratory and Sanford Underground Research Facility, respectively. LBNF/DUNE is the first international mega-science project hosted on U.S. soil and is supported by funding from over 30 partner countries and 1000 scientists worldwide.[26]

These examples underscore the need for large-scale collaboration and coordination among countries to drive progress on fundamental scientific understanding and addressing complex problems. The COVID-19 pandemic provided a stark case study of how timely international S&T collaboration and coordination can drive innovation and solutions: by April 2020, four months after the first cases of the SARS-CoV-2 virus were officially reported, multi-national partnerships in the public and private sectors contributed to the increasing knowledge of the virus, with open science practices and digital platforms enhancing these cooperative efforts.[27] This collaboration contributed to the unprecedented speed with which vaccines against COVID-19 were developed, building on years of previous international collaborations on similar viruses and related vaccine development.[28] Similarly, the long-term benefits of international collaboration are evident from the work of the Botswana-Harvard AIDS Institute Partnership lab, which was founded in 1996 as a partnership between Harvard University and Botswana's Ministry of Health with funding from NIH to carry out research on HIV. The lab has since become an independent institution, a research center of excellence in Africa, and was the first lab globally to identify the omicron variant of COVID-19.[29]

In parallel with these pandemic-related research efforts taking place outside of the government, the U.S. government worked through international partner engagements to share samples for testing, share insights into testing protocols and decontamination, and share S&T advice. For example, leveraging existing S&T networks, the U.S. and "Five Eyes" partners (Australia, Canada, New Zealand, and United Kingdom) established a biosecurity network to discuss complementary efforts and studies that informed domestic COVID-19 response operations.

Finding 3: The United States sets and informs standards for global science.

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[24] European Southern Observatory (ESO). No date. "ALMA." https://www.eso.org/public/usa/teles-instr/alma.

[25] The Atacama Large Millimeter/submillimeter Array (ALMA). 2019. "Press Releases: Astronomers Capture the First Image of a Black Hole". https://www.almaobservatory.org/en/press-releases/astronomers-capture-first-image-of-a-black-hole/.

[26] Fermilab. No date. "DUNE at LBNF: DUNE Collaboration." https://lbnf-dune.fnal.gov/people/dune-collaboration/. For example, the U.K. Government has invested £65 million in LBNF-DUNE. Butterworth, Jon. 2017. "UK invests £65m in Deep Underground Neutrino Experiment in US." *The Guardian*. September 24, 2017. https://www.theguardian.com/science/life-and-physics/2017/sep/24/uk-invests-65m-in-deep-underground-neutrino-experiment-in-us.

[27] Druedahl, Louise C.; Minssen, Timo; Price, W. Nicholson. 2021. "Collaboration in times of Crisis: A study on COVID-19 vaccine R&D partnerships." https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8410639/.

[28] The first vaccine to be approved for use in the United States was the product of a collaboration between American and German biotechnology companies (Pfizer and BioNTech, respectively).

[29] Gavin, Michelle. 2022. "Inside the Lab that Identified Omicron." https://www.thinkglobalhealth.org/article/inside-lab-identified-omicron; Botswana-Harvard AIDS Institute Partnership. No date. "Botswana-Harvard AIDS Institute Partnership (BHP)." https://sites.sph.harvard.edu/global-health-research-partnership/sites-2/bostwana-harvard-aids-institute-partnership-bhp/.

U.S. experts inform and lead international discussions on technology, standards, ethics, and the responsible practice of science, but are increasingly being challenged by outside actors like the PRC.

By maintaining strong connections to national metrology institutes (NMIs) in LMICs, the U.S. government plays a central role in supporting research and collaborations that have an impact on international technical standards setting. Through advancing measurement science and S&T standard development, the United States can reinforce its leadership and build stronger ties between other NMIs and industry. These relationships influence the adoption of developing better measurement capabilities that can impact global trade. U.S. government agencies also work together to establish transparent, science-based standards and to engage with international institutions and fora to promote agreement on technical standards and policies. For example, it is important to establish standards around powerful emerging technologies such as CRISPR, which can be used for gene editing,[30] and artificial intelligence (AI).[31] Another good example includes the contributions of U.S. authors, institutions, and agencies to the Intergovernmental Panel on Climate Change.[32] Leadership in these institutions is increasingly being chosen for strategic reasons by countries like the PRC to define the international landscape, and the United States will be increasingly challenged by initiatives like "China Standards 2035," to maintain international influence in this domain.[33]

In addition to technical standard-setting, U.S. government agencies have an important role to play in the establishment of rigorous scientific practices, via both formal and informal means.[34] Federal agencies emphasize the need to consider principles of scientific integrity,[35] research integrity,[36]

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30 CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) is an approach that corrects gene mutations in relevant tissues without the risk of passing those changes on to a future generation. National Institutes of Health (NIH). 2020. "The CRISPR Revolution." https://www.nih.gov/about-nih/what-we-do/nih-turning-discovery-into-health/crispr-revolution/. NIH is also involved in ongoing efforts to assess and ensure the safe and ethical use of this technology. https://www.nih.gov/news-events/gene-editing-digital-press-kit#safe.

31 NIST published a draft AI Risk Management Framework in 2022 as part of its interagency coordinating role on AI standards and guidance National Institute of Standards and Technology (NIST). No date. "AI Risk Management Framework." https://www.nist.gov/itl/ai-risk-management-framework .

32 Intergovernmental Panel on Climate Change (IPCC). 2022. "Climate Change 2022: Impacts, Adaptation, and Vulnerability." https://www.ipcc.ch/report/sixth-assessment-report-working-group-ii/. U.S. experts made significant contributions to the recently-released Sixth Assessment Report on impacts, adaptation, and vulnerability, including the limits of human society to adapt to a changing planet.

33 Cronk, Terry M. Department of Defense. 2021. "Tech Advantage Critical to Prevail in Strategic Competition with China, DOD Official Says." https://www.defense.gov/News/News-Stories/Article/Article/2835616/tech-advantage-critical-to-prevail-in-strategic-competition-with-china-dod-offi/.

34 Formal good scientific practices could include incorporating scientific integrity or research security training into grant agreements. Informal good scientific practices could include having discussions of the importance of scientific integrity as part of scientific presentations.

35 "Scientific integrity" is defined as, "The condition resulting from adherence to professional values and practices when conducting, reporting, and applying the results of scientific activities that ensures objectivity, clarity, and reproducibility, and that provides insulation from bias, fabrication, falsification, plagiarism, inappropriate influence, political interference, censorship, and inadequate procedural and information security." U.S. Department of Agriculture. n.d. "Scientific Integrity and Research Misconduct." https://www.usda.gov/our-agency/staff-offices/office-chief-scientist-ocs/scientific-integrity-and-research-misconduct.

36 "Research integrity" is defined as, "The use of honest and verifiable methods in proposing, performing, and evaluating research; reporting research results with particular attention to adherence to rules, regulations, and guidelines; and following commonly accepted professional codes or norms." NSTC Subcommittee on Research Security, Joint Committee on the Research Environment. 2022. "Guidance for Implementing National Security Presidential Memorandum 33 (NSPM-33) on National Security Strategy for United States Government-Supported Research and Development". https://www.whitehouse.gov/wp-content/uploads/2022/01/010422-NSPM-33-Implementation-Guidance.pdf.

research security,[37] and open science[38] in their collaborative research efforts, and to implement policies and practices that guard the scientific enterprise.[39] U.S. scientists and experts also provide positive examples of technical collaboration and capacity-building programs with LMICs.

Finding 4: The United States attracts and retains STEM talent, but can do more to ensure that international talent chooses to come to the United States and remain.

Foreign-born STEM researchers provide key research insights and contribute an estimated 1.7-1.9% value added to U.S. GDP.[40] As other nations improve their scientific base through education and training opportunities, research promotion, and foreign talent recruitment programs to drive their own competitiveness, the United States will increasingly need to enhance the attractiveness of our own research ecosystem to attract and retain both foreign and domestic talent.

The United States remains a global leader in higher-level STEM education. More international students come to the United States than any other country,[41] and the United States awards more doctorates than any other nation.[42] Foreign talent contributed an estimated $367 billion to $409 billion in value-added labor and $260 billion to $394 billion to R&D-intensive industries in 2019; foreign talent contributes net values of $200,000 to $700,000 per individual to the U.S. economy every three years.[43]

In 2019, 19% of the U.S. STEM workforce was made up of foreign-born workers, and approximately 50% of foreign-born workers in the United States with science and engineering degrees were from Asian countries, particularly India and the PRC.[44] Nearly half of the doctoral workers in science and engineering occupations in the United States were foreign-born workers on temporary visas at the time

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37 "Research security" is defined as, "Safeguarding the research enterprise against the misappropriation of research and development to the detriment of national or economic security, related violations of research integrity, and foreign government interference." NSTC Subcommittee on Research Security, Joint Committee on the Research Environment. 2022. "Guidance for Implementing National Security Presidential Memorandum 33 (NSPM-33)." https://www.whitehouse.gov/wp-content/uploads/2022/01/010422-NSPM-33-Implementation-Guidance.pdf.

38 "Open science" is defined as, "Unhindered access to scientific articles, access to data from public research, and collaborative research enabled by information and communication technology tools and incentives." Organization for Economic Cooperation. No date. "Open Science." https://www.oecd.org/sti/inno/open-science.htm.

39 White House Office of Science and Technology Policy. 2022. "Memorandum for the Heads of Executive Departments and Agencies: Ensuring Free, Immediate, and Equitable Access to Federally Funded Research." https://www.whitehouse.gov/wp-content/uploads/2022/08/08-2022-OSTP-Public-Access-Memo.pdf.

40 Crane, Keith W.; Colvin, Thomas J.; Goldman, Abby R; Grumbling, Emily R; Ware, Andrew B. 2021. "Economic Benefits and Losses from Foreign STEM Talent in the United States." https://www.ida.org/research-and-publications/publications/all/e/ec/economic-benefits-and-losses-from-foreign-stem-talent-in-the-united-states.

41 National Science Board. 2022. "The State of US Science and Engineering 2022." https://ncses.nsf.gov/pubs/nsb20221/u-s-and-global-stem-education-and-labor-force.

42 In 2018, the United States produced 41,071 doctoral candidates with the PRC in second place (39,768) and India in third place (26,890). National Science Board. 2022. "The State of U.S. Science and Engineering 2022, U.S. and Global STEM Education and Labor Force." https://ncses.nsf.gov/pubs/nsb20221/u-s-and-global-stem-education-and-labor-force.

43 Crane, Keith W.; Colvin, Thomas J.; Goldman, Abby R; Grumbling, Emily R; Ware, Andrew B. 2021. "Economic Benefits and Losses from Foreign STEM Talent in the United States." https://www.ida.org/research-and-publications/publications/all/e/ec/economic-benefits-and-losses-from-foreign-stem-talent-in-the-united-states.

44 National Science Board. 2022. "The State of U.S. Science and Engineering 2022, U.S. and Global STEM Education and Labor Force." https://ncses.nsf.gov/pubs/nsb20221/u-s-and-global-stem-education-and-labor-force.

of their graduation; these graduates are a key category of STEM workers.[45] A decade of data indicates that more than 75% of these foreign-born doctorate recipients state that they intend to live in the United States in the year after graduation, with students from the PRC and India more likely to stay compared to students from Europe and Republic of Korea.[46]

STEM talent is crucial to U.S. global S&T leadership because successful R&D and innovation rely upon a diverse and knowledgeable workforce. The United States currently ranks first globally in high R&D-intensity industries, representing approximately one-third of the global total, with the PRC and the EU both in second place at approximately 20% of the total.[47] Ensuring that STEM talent from around the world views the United States as the destination of choice for education and work will be essential to continued U.S. leadership; as part of these efforts, it will be important to diversify the source nations for the STEM students and workers that the United States attracts to ensure that the U.S. STEM workforce truly represents the best global talent.

The United States has historically attracted foreign STEM talent, but the COVID-19 pandemic, visa restrictions, and related factors demonstrated how quickly conditions can change: foreign student enrollment at U.S. educational institutions dropped by 15% in the 2020/21 academic year, continuing a decline in growth rate that began in 2014-15.[48]

- ***Recommendation 1****:* Explore mechanisms to support students and postdocs from LMICs to engage with the U.S. S&T enterprise.
- ***Recommendation 2:*** Conduct research to understand why STEM talent leaves the United States or chooses to go to other countries, including examining the entire innovation pipeline to identify research, development, regulatory, statutory, capacity, and infrastructure challenges to STEM talent recruitment and retention.

Finding 5: The United States can achieve diplomatic and national security goals with international S&T engagement.

The United States benefits from engaging with allied and partner countries on scientific projects and topics and more broadly on S&T policy.

S&T cooperation advances U.S. foreign policy and national security interests and plays a role in shaping geopolitical structures, helping to bridge tensions between adversaries and develop new ties as well as

[45] The National Science Board reports that 45% of doctoral workers are foreign-born. National Science Board. 2022. “The State of U.S. Science and Engineering 2022, U.S. and Global STEM Education and Labor Force.” https://ncses.nsf.gov/pubs/nsb20221/u-s-and-global-stem-education-and-labor-force.

[46] National Science Board. 2022. “The State of U.S. Science and Engineering 2022, U.S. and Global STEM Education and Labor Force.” https://ncses.nsf.gov/pubs/nsb20221/u-s-and-global-stem-education-and-labor-force.

[47] “High R&D-intensive industries” include aircraft manufacturing; pharmaceuticals; computer, electronic, and optical products; computer software publishing; and scientific R&D services. The United States ranks third behind the PRC and the EU in medium-high R&D intensive industries, which include information technology services, machinery, transportation equipment, and scientific instruments. National Science Board. 2022. “Production and Trade of Knowledge- and Technology-Intensive Industries.” https://ncses.nsf.gov/pubs/nsb20226/production-patterns-and-trends-of-knowledge-and-technology-intensive-industries.

[48] The United States experienced slowing enrollment growth rates prior to the COVID-19 pandemic. Between the 2014/15 and 2018/19 academic years, annual growth rates slowed from 10% to 0.05%, and enrollment rates fell to -1.8% during the 2019/20 school year. The pandemic resulted in a -15% annual growth rate in 2020/21. Open Doors. No date. “Enrollment Trends.” https://opendoorsdata.org/data/international-students/enrollment-trends/.

strengthen cooperation and collaboration with allies and partners. This cooperation can also help reinforce coalition-building to ensure that the United States and its allies and partners stay ahead of adversaries in critical technologies.[49] For example, the U.S.-Ireland R&D Partnership Program supports proposals that include researchers from the United States, Republic of Ireland, and Northern Ireland (part of the United Kingdom), facilitating collaborations among nations with historically strained ties.[50] The Mekong Water Data Initiative (MWDI) seeks to improve the transboundary management of the Mekong River through technical capacity building and promoting science-based decision making. MWDI also improves access to essential water data through MekongWater.org, a clearinghouse for data sharing and tools that can empower Mekong River countries to sustainably manage their shared natural resources.[51] The Agriculture Innovation Mission for Climate (AIM for Climate) initiative is co-led by the United States and the United Arab Emirates[52] and joined by over 200 other government and non-government partners that together seek to increase and accelerate agriculture and food systems innovation in support of climate action. To achieve this goal, AIM for Climate participants intend to significantly increase and accelerate investment in – and other support for – climate-smart agriculture and food systems innovation over five years (2021-2025).[53,54] The Middle East Regional Cooperation Program, funded by USAID, was established in 1981 to facilitate research collaboration between Egyptian and Israeli scientists following the signing of the Camp David Accords.[55] Since 1993, the program has expanded to include researchers from Jordan, Lebanon, Morocco, Tunisia, the West Bank and Gaza, and is open to supporting projects with partners in the Maghreb and Gulf regions.

U.S. national security interests are also served by international S&T engagement. For example, DHS recently completed the Next Generation Incident Command System project, which brought a new communications technology to four Balkan countries that often have regional tensions (Croatia, Montenegro, Bosnia and Herzegovina, and North Macedonia).[56] The technology for the project was developed for wildland fire monitoring in the United States, but it was adapted for use with first responders in the partner countries. During the four-year project, Montenegro and North Macedonia became full members of NATO, and the system is currently being used to coordinate Ukrainian refugee processes in the region. This project demonstrates the value of collaborative S&T solutions, and it also shows how the relationships developed during collaboration are often of equal value to the technology, cultivating a community of practice around common goals and interests before crisis.

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[49] For more on critical technologies, see: Shyu, Heidi. 2022. "USD(R&E) Technology Vision for an Era of Competition." Official memorandum. Washington, D.C.: Department of Defense. https://www.cto.mil/wp-content/uploads/2022/02/usdre_strategic_vision_critical_tech_areas.pdf.

[50] Science Foundation Ireland (SFI). No date. "US-Ireland R&D Partnership Programme." https://www.sfi.ie/funding/funding-calls/us-ireland-rd-partnership/.

[51] The United States worked closely with Lower Mekong Initiative countries, the Mekong River Commission, the Friends of the Lower Mekong, and more than 60 private, academic, and non-profit stakeholders to design and launch the clearinghouse. Mekong-U.S. Partnership. 2020. "Mekong Water Data Initiative (MWDI)." https://mekonguspartnership.org/projects/mekong-water-data-initiative-mwdi/.

[52] USDA. 2021. "Launching Agriculture Innovation Mission for Climate." https://www.usda.gov/media/press-releases/2021/04/23/launching-agriculture-innovation-mission-climate.

[53] AIM for Climate. 2021. "Agriculture Innovation Mission for Climate." https://www.aimforclimate.org.

[54] As of November 2021, 40 non-governmental partners have announced Innovation Sprints in areas such as AI to boost agricultural productivity and to "climate-proof" 0.5 billion acres around the world by 2024. Connected Technology Solutions (CTS). 2021. "AIM for Climate Announces $193 million in climate-smart agriculture innovation sprints." http://connectedtechnologysolutions.co.uk/aim-for-climate-announces-193-million-in-climate-smart-agriculture-innovation-sprints/.

[55] USAID. 2021. "Middle East Regional Cooperation (MERC)." https://www.usaid.gov/where-we-work/middle-east/merc.

[56] North Atlantic Treaty Organization (NATO). 2020. "NATO Science presents: The Next-Generation Incident Command System." https://www.nato.int/cps/en/natohq/news_179991.htm.

International S&T engagement provides an opportunity to build relationships with and capacity in partner countries by either sending U.S. researchers overseas to teach specific skills or by funding foreign researchers to come to the United States. The Fulbright Program supports academic exchange for U.S. and foreign researchers alike, providing awards to approximately 8,000 students, researchers, teachers, and others from the United States and 160 countries annually.[57] The Science, Mathematics, and Research for Transformation (SMART) Scholarship-for-Service Program, funded by DoD and open to students from the United States, Australia, Canada, New Zealand, and the United Kingdom, is a combined educational and workforce development opportunity for STEM students that offers scholarships for undergraduate, master's, and doctoral students currently pursuing a degree in one of 21 STEM disciplines.[58] The Partnerships for Enhanced Engagement in Research (PEER) program in USAID’s Innovation, Technology, and Research Hub[59] provides grants to scientists in LMICs, partnering them with U.S. government-funded researchers.[60] Experienced U.S. scientists and engineers are selected for the DOS’s U.S. Science Envoy Program to engage internationally to strengthen bilateral S&T relationships, communicate with international audiences and advance U.S. science and foreign policy goals.[61] The DOS’s Embassy Science Fellows (ESF) Program places U.S. government scientists from across the executive branch in short-term assignments at U.S. posts overseas, expanding international S&T collaboration.[62] The American Association for the Advancement of Science’s (AAAS’s) Science and Technology Policy Fellowship program includes Overseas Fellowships that place Ph.D. scientists at USAID missions abroad.[63] The International Visitor Leadership Program provides current and emerging world leaders with the opportunity to participate in professional engagement in a variety of fields, including on S&T topics, via short-term visits to the United States, who thereby gain S&T expertise and build relationships with U.S. scientific and diplomatic staff.[64]

The DOS has dozens of Foreign Service Officers in U.S. embassies around the world, who work specifically to advance key U.S. priorities in the environmental, scientific, technological, and public health (ESTH) sphere. To address regional and transboundary environmental issues – and to support officers working on related environmental or health issues – the DOS maintains 12 regional environmental hubs, located in embassies in San Jose, Costa Rica; Lima, Peru; Gaborone, Botswana; Addis Ababa, Ethiopia; Accra, Ghana; Amman, Jordan; Bangkok, Thailand; Suva, Fiji; Kathmandu, Nepal; Nur-Sultan, Kazakhstan; Copenhagen, Denmark; and Budapest, Hungary. Regional environmental hub officers complement ESTH officers in bilateral U.S. missions by engaging multiple

[57] The Fulbright Program has supported over 400,000 individuals from the United States and 165 countries since 1946. State Department Bureau of Educational and Cultural Affairs. No date. “Fulbright Program Overview.” https://eca.state.gov/fulbright/about-fulbright/fulbright-program-overview.

[58] SMART scholars receive full tuition, annual stipends, internships, and guaranteed employment with the DoD after graduation. SMART Scholarship Program. No date. “SMART Scholarship Program.” https://www.smartscholarship.org/smart.

[59] USAID. 2022. “Innovation, Technology, And Research.” https://www.usaid.gov/innovation-technology-research.

[60] PEER is implemented by the National Academies of Sciences, Engineering and Medicine in partnership with seven Federal agencies. U.S. National Academies of Sciences, Engineering, and Medicine. 2022. “About PEER.” https://sites.nationalacademies.org/PGA/PEER/PGA_147205.

[61] U.S. Department of State. No date. “U.S. Science Envoy Program.” https://www.state.gov/programs-office-of-science-and-technology-cooperation/u-s-science-envoy-program/.

[62] U.S. Department of State. No date. “Embassy Science Fellows Program.” https://www.state.gov/programs-office-of-science-and-technology-cooperation/embassy-science-fellows-program/.

[63] AAAS. 2021. “STPF Overseas Fellowship: A Deep Dive with International Policy Impact.” https://www.aaas.org/news/stpf-overseas-fellowship-deep-dive-international-policy-impact.

[64] U.S. Department of State. No date. “International Visitor Leadership Program.” https://exchanges.state.gov/non-us/program/international-visitor-leadership-program-ivlp.

countries simultaneously on issues of concern, with the aim of promoting regional environmental cooperation, sharing of environmental data, and adoption of environmentally sound policies that will benefit all countries in that area.

DOS also launched the complementary Regional Technology Officers program in 2021, to enhance the Department's ability to promote U.S. leadership in technology, secure U.S. economic assets, and ensure technology ecosystems support U.S. values through regional cooperation and public diplomacy. This program has placed Foreign Service Officers in Tokyo, Japan; Sydney, Australia; and São Paulo, Brazil; and it is anticipated to grow to twelve officers positioned globally in the coming years.

These short-term opportunities are beneficial, yet they are limited in their ability to substantially move the needle in reducing barriers between allied or partner programs or creating new joint programs. The United States would benefit substantially from dedicated S&T program officer exchange, similar to long-term diplomatic or defense exchanges such as the Transatlantic Diplomatic Fellows Program and the U.S. DoD Personnel Exchange Program, including the Engineer and Scientist Exchange Program,[65] with the goal of creating a community of practice among allied and partnered scientific and technical organizations that helps to reduce divergence, improve communication, and set norms and values among major research organizations. An example of recent success in this area is a 2021 summit between the United States and EU, which resulted in commitments to set up staff exchanges between research funding agencies, collaborate on research and standards development in the areas of biotechnology and genomics, cooperate on cybersecurity information sharing, and expand cooperation between the EU Joint Research Centre and NIST.[66]

Collaboration among sectors can also be beneficial to U.S. S&T leadership. An example of this is the Global Innovation through Science and Technology (GIST) program, a DOS-led program that connects American businesses with global S&T entrepreneurs and has reached over 27 million innovation community members globally since 2011.[67] GIST addresses economic and developmental challenges through providing entrepreneurs with networking, skills building, mentoring, and access to financing made possible through competitions, startup trainings, and interactive online programs. The program has also provided training for over 15,000 startups that have gone on to generate over $250 million in revenue.[68] USAID's Development Innovation Ventures program (DIV) supports innovators and researchers around the world to test new ideas, take strategic risks, build evidence of what works, and advance the best solutions. In its first three years, DIV's portfolio returned over $17 in social benefit for each dollar awarded—a 17:1 return on investment.[69]

- ***Recommendation 3:*** Expand the use and scope of the Embassy Science Fellows (ESF) and other exchange programs, as well as long-term detail opportunities between government agencies in international S&T. Work to ensure that these opportunities are open to all levels of knowledge and experience to break down siloes and provide cross-agency integration at various professional levels. Identify and remove barriers for participation in these programs to better promote principles of DEIA and ensure that the international S&T workforce better reflects the U.S. population and U.S. scientific community

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[65] U.S. Department of Defense, Secretary of the Air Force International Affairs. No date. "Engineer and Scientist Exchange Program." https://www.safia.hq.af.mil/Force-Development/Engineer-and-Scientist-Exchange-Program/.

[66] The White House. 2021. "U.S.-EU Summit Statement." June 15, 2021. https://www.whitehouse.gov/briefing-room/statements-releases/2021/06/15/u-s-eu-summit-statement/.

[67] GIST. No date. "About GIST." https://www.gistnetwork.org/about.

[68] GIST. No date. Home Page. https://www.gistnetwork.org.

[69] USAID. No date. "Development Innovation Ventures." https://www.usaid.gov/div.

- ***Recommendation 4:*** Explore transnational exchanges between U.S. and foreign technical agencies to increase opportunities for collaboration with close partners while addressing barriers to cooperation.

Gaps in the U.S. Approach to International S&T Engagement

The United States is succeeding in S&T in the areas described above, but is also losing ground in significant ways; a common trend is the PRC's rapid advancement in many areas of S&T. This section describes issues that have the potential to compromise U.S. global leadership. The highlighted gaps also identify opportunities to build or re-establish U.S. leadership in critical technology areas where international engagement will be essential to advancement.

Gap 1: The United States is missing out on both short- and long-term strategic opportunities to engage internationally, and is being left behind as a result.

Countries able to engage globally on S&T issues, including through funding for international initiatives, will have a strategic advantage.

The United States leads the world in R&D spending, but has been gradually losing ground to the PRC, whose annual R&D expenditure increased by more than 15 times between 2000 and 2019.[70] The number of science publications by U.S. researchers grew from 2010 to 2020, but those by PRC researchers more than doubled in the same time period.[71] The PRC's most recent five-year plan includes goals to become a powerhouse in S&T, education, and talent by 2035,[72] and the Intelligence Community's 2022 National Threat Assessment states that the PRC is using its economic, technological, and diplomatic influence to achieve its global ambitions. [73]

The U.S. government generally has a near-future focus with few long-term commitments in international S&T. As a result, funding mechanisms specific to facilitating or supporting bilateral or multilateral international scientific partnerships or to support international sharing of resources may not be available; Federally funded research is ongoing, but international engagement on this research is often not prioritized. Lead Agency[74] Opportunities provide the United States and other countries with simplified opportunities for strategic collaboration, but generally only function when both

[70] The PRC contributed $32.9 billion to global R&D in 2000 and $525.7 billion in 2019. National Science Board. 2022. "The State of U.S. Science and Engineering 2022, U.S. and Global Research and Development." https://ncses.nsf.gov/pubs/nsb20221/u-s-and-global-research-and-development.

[71] Science publications from the United States grew from 409,500 in 2010 to 455,900 in 2020. Science publications from the PRC numbered 308,800 in 2010 and 669,700 in 2020. National Science Board. 2022. "The State of U.S. Science and Engineering 2022, U.S. and Global Science and Technology Capabilities." https://ncses.nsf.gov/pubs/nsb20221/u-s-and-global-science-and-technology-capabilities.

[72] For an unofficial English translation, see: Center for Security and Emerging Technology (CSET). 2021. "Translation: Outline of the People's Republic of China 14th Five-Year Plan for National Economic and Social Development and Long-Range Objectives for 2035." https://cset.georgetown.edu/publication/china-14th-five-year-plan/.

[73] "Beijing is increasingly combining growing military power with its economic, technological, and diplomatic clout to strengthen CCP [Chinese Communist Party] rule, secure what it views as its sovereign territory and regional preeminence, and pursue global influence." *Annual Threat Assessment of the U.S. Intelligence Community*. 2022. Office of the Director of National Intelligence. https://www.dni.gov/files/ODNI/documents/assessments/ATA-2022-Unclassified-Report.pdf.

[74] "Lead Agency" is defined as "the United States Government agency designated to coordinate the interagency oversight of the day-to-day conduct of an ongoing operation." U.S. Department of Defense. 2021. *DOD Dictionary of Military and Associated Terms*. https://www.jcs.mil/Portals/36/Documents/Doctrine/pubs/dictionary.pdf.

governments have substantially similar capacity, limiting their utility for improving cooperation with emerging economies. As an example, this structure can make it challenging for the United States to work with countries that are experiencing more immediate impacts of global climate change, such as small island developing States. Enabling collaboration and frontline interactions of operators and scientists in these nations would enhance U.S. preparations for the impacts of climate change, as well as provide opportunities to test U.S. mitigation proposals and technologies in their environments.

Financial and long-term strategic planning leverage and near-peer competitor status has given the PRC, in particular, the ability to direct funding for science, as well as loans and other instruments for high technology and space programs, including to other countries where U.S. involvement is conspicuously absent. For instance, the PRC has increased its presence in international organizations like the World Academy of Sciences by offering awards and scholarships to LMICs that are sponsored by the Chinese government or other institutions.[75] Likewise, the PRC has increased its presence in Africa in support of African space programs, offering financing, loans, and partnerships, such as on the Beidou Navigation Satellite System or support for Sudan's military and civil space program. The PRC has also established partnerships with high-income country institutions through joint funds and other instruments. While modest in terms of funding and publication output, these programs can have significant soft power impact, particularly when the United States is unable to offer partners similar opportunities. In addition, countries whose economies are more dependent on tourism are seeking to expand S&T capacity to offset future dependence on tourism in a post-COVID world.[76] These countries may not qualify for U.S. development assistance, but near-peer competitors are able to seize these opportunities, similar to engagement seen throughout Africa.[77]

The United States is frequently unable to support long-term membership in international scientific organizations/programs and provide STEM expertise to international organizations, which has consequences for U.S. participation in large-scale research activities and may negatively affect the reputation of the United States while providing opportunities for strategic competitors. Negative perceptions of U.S. reciprocity in funding may reduce the ability of the United States to overcome obstacles to cooperation and to build S&T alliances. Reducing collaboration with likeminded nations creates potential risks that the United States will lose out on the opportunity to build research infrastructure and develop commonly agreed upon research standards.

While countries often seek partnerships with the United States, particularly via joint calls and other financial partnership instruments, Federal science funding for U.S. researchers generally focuses on identifying the highest-impact proposals. Consequently, science agencies are generally not organized or resourced to effectively develop joint programs whose purpose is to improve international relationships or build capacity. Likewise, development programs at USAID are not designed nor

[75] For example, The World Academy of Sciences (TWAS). No date. "CAS-TWAS Centres of Excellence". https://twas.org/cas-twas-centres-excellence.

[76] For example, the Economic Commission for Latin America and the Caribbean (ECLAC) present S&T as an opportunity to fundamentally restructure their economies and societies post-COVID. United Nations. No date. "Economic Commission for Latin America and the Caribbean". ECLAC. 2021. "Science, Technology and Innovation are Crucial for Facing the Pandemic and Moving Towards a Transformative Recovery with Equality and Sustainability in the Region." December 13, 2021. https://www.cepal.org/en/news/science-technology-and-innovation-are-crucial-facing-pandemic-and-moving-towards-transformative.

[77] For example, Cuba joined the PRC's, Belt and Road Initiative in 2018, and ECLAC signed a Joint Action Plan for Cooperation in Key Areas with the PRC in December 2021 at the same meeting where they discussed the importance of S&T for post-COVID recovery. Foster, S. 2022. "Belt & Road encircles Latin America and the Caribbean". https://asiatimes.com/2022/01/belt-road-encircles-latin-america-and-the-caribbean/.

intended to serve as deliverables in the bilateral scientific engagements, which are highly sought after by international partners, and are not at such a scale that can easily be leveraged for the purposes of advancing bilateral relations, particularly compared to the scale and types of investment offered by the PRC. This has also placed the DOS and funding agencies in a continual response mode with respect to requests made by international partners and has limited the bandwidth and ability of agencies to develop proactive programs to meet strategic international scientific or foreign policy objectives.

S&T engagement with LMIC partners should account for some degree of capacity-building and acknowledge the differentiation of needs, particularly when compared with engagements with high-income partners. Barriers to collaboration, capacity, and interest affect the ability of science agencies to partner with LMICs, often leaving the United States behind as strategic competitors without similar limitations develop international partnerships. The large number of potential LMIC partners and limited available funding also means that U.S. research partnership investments are often short and intermittent, leaving little room to establish the needed capacity and meaningful relationships. This situation negatively impacts U.S. interests in multilateral fora and standards-setting bodies by enabling countries with the ability to program over longer periods of time the opportunity to increase their influence in highly-technical areas.

Even with the aforementioned challenges, there are opportunities to cultivate and organize collaboration around initiatives for shared challenges with international partners and relevant commercial markets. For example, the International Forum to Advance First Responder Innovation (IFAFRI) established by DHS provides a cooperative forum for 15 countries and the European Commission to define common capability gaps, share information on available technologies to the first responder community, and characterize the global first responder market to guide industry on market opportunities. U.S. participation in IFAFRI enables U.S. first responder needs to be elevated to all IFAFRI partners investing in technologies for public safety. However, this forum is not able to support cost-sharing activities beyond in-kind contributions and is not inclusive of LMICs.

There are several examples of collaborative large-scale S&T facilities where participation is of interest to U.S. scientists: the Square Kilometer Array (SKA), an international project that will site telescopes in Australia and South Africa as well as eight other African countries to carry out research on the origins of the universe, among other topics;[78] the Synchrotron-light for Experimental Science and Applications in the Middle East (SESAME) research center, an intergovernmental organization established under UNESCO and modelled after CERN focusing on advancing research in the Middle East and surrounding regions;[79] and the Extreme Light Infrastructure (ELI), a distributed laser-based research consortium based in Czechia, Hungary, and Romania.[80]

- ***Recommendation 5:*** Strengthen the U.S. research and innovation environment to enable U.S. global S&T leadership, including working through multilateral fora, increasing opportunities for participation by and partnerships with LMICs, and motivating private sector R&D and STEM professionals to remain in the United States.
- ***Recommendation 6:*** Consider the development of flexible and longer-term approaches to funding international collaborative science to compete with other countries' longer-term research funding

[78] The SKA is a collaboration among 16 countries representing 40% of the world's population (Australia, Canada, the PRC, France, Germany, India, Japan, Italy, the Netherlands, Portugal, South Africa, South Korea, Spain, Sweden, Switzerland, and the United Kingdom). Square Kilometer Array Organization (SKAO). No date. "SKAO Public Website." https://www.skatelescope.org/.

[79] UNESCO. 2021. "SESAME." https://en.unesco.org/themes/science-sustainable-future/sesame.

[80] ELI – ERIC. No date. "What is ELI?" https://eli-laser.eu/.

initiatives, such as those enabled by the PRC's five-year plans or the EU's seven-year multiyear financial framework.

Gap 2: The United States spearheads a limited number of ambitious, large-scale international S&T research collaborations for specific topics.

Foreign governments are increasingly supportive of multinational research consortia, and they are willing to spend billions of dollars to participate; the United States has no similar science diplomacy initiatives.

Horizon Europe is the EU's signature research and innovation funding program with a €95.5 billion (approximately $105 billion) budget under the EU's seven-year multiannual financial framework for 2021-2027.[81] Funding is available to all EU member states as well as a group of associated countries within and outside of Europe and a number of LMICs, intentionally designed to support international collaboration.[82] U.S. researchers and research institutions can participate in Horizon Europe, but they can receive only limited supporting funds from the EU.[83] The size and scope of Horizon Europe provides global S&T research opportunities, but may also prompt countries to leverage their own resources in support of the program.[84] The United Kingdom, no longer a member of the EU, has budgeted £6.9 billion (approximately $9 billion) through 2025 to participate in European programs including Horizon Europe,[85] and Switzerland (also not a member of the EU) budgeted CHF400 million (approximately $435 million) to cover its scientists' participation in 2021.[86] Eighteen non-EU countries are either currently contributing their own funds for scientists or are under a transitional arrangement allowing their scientists to participate in Horizon Europe.[87]

The ability to support international research consortia and leverage funding from other countries to do so has considerably increased the EU's presence and influence in international S&T policy and programming. Most recently, Canada and New Zealand announced the conclusion of exploratory talks

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[81] European Commission, Directorate-General for Research and Innovation. 2021. "Horizon Europe, Budget: Horizon Europe – the Most Ambitious EU Research & Innovation Programme Ever." Publications Office. https://data.europa.eu/doi/10.2777/202859.

[82] European Commission. 2022. List of Participating Countries in Horizon Europe. https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/common/guidance/list-3rd-country-participation_horizon-euratom_en.pdf.

[83] European Commission. No date. "United States." https://ec.europa.eu/info/research-and-innovation/strategy/strategy-2020-2024/europe-world/international-cooperation/united-states_en.

[84] For example, the government of Mexico is providing financial support for Mexican scientists participating in successful Horizon Europe projects. European Commission. 2022. "CONACYT Announces its Commitment to Finance Mexican Institutions and Researchers Participating in Horizon Europe Calls." March 24, 2022. https://ec.europa.eu/info/news/conacyt-announces-its-commitment-finance-mexican-institutions-and-researchers-participating-horizon-europe-calls-2022-mar-24_en.

[85] The budgeted £6.9 billion also funds U.K. participation in the European Atomic Energy Community (Euratom) and the International Thermonuclear Experimental Reactor (ITER). U.K. Government. 2021. Autumn Budget and Spending Review. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1043688/Budget_AB2021_Print.pdf.

[86] Swissinfo.ch. 2021. "Horizon Europe: Government Pledges Funds to Plug Shortfalls." October 21, 2021. https://www.swissinfo.ch/eng/horizon-europe--swiss-government-pledges-funds-to-plug-shortfalls/47043386.

[87] European Commission. 2022. "List of Participating countries in Horizon Europe." https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/common/guidance/list-3rd-country-participation_horizon-euratom_en.pdf.

and commencement of formal negotiations toward joining Horizon Europe as associate members,[88] and other countries, including Japan and Singapore, are also in the process of talks toward association.[89] U.S. diplomats report that some of our closest allies and partners have begun to negatively compare the level of U.S. commitment to its scientific relationships with that of the EU and other countries that are able to directly program strategic international collaboration opportunities.

Additionally, the PRC has significantly increased its international scientific collaborations, including a focus on South-South collaboration with S&T programs in Africa, South Asia, and Latin America. The PRC's ambassador to the United States, Ambassador Qin Gang, highlighted in a 2021 interview[90] three specific measures that the PRC has engaged in, including: A) the sharing of mature and applicable technologies, putting them to local use to boost those countries' economic development; B) the establishment of joint laboratories, thereby conducting joint research in agriculture, radio and television, clean energy and more; and C) holding training classes on applicable technologies and carrying out exchanges among young scientists. The PRC's implementation of the Belt and Road Science, Technology, and Innovation Cooperation Action Plan has supported over 8,300 young foreign scientists to work in PRC institutions. The PRC has also established 33 joint laboratories and 5 technologies transfer platforms with less developed countries.

- ***Recommendation 7:*** Explore the creation of a flexible mechanism within the DOS to support joint S&T goals, research, and innovation with foreign partners. Projects and initiatives could include consortia support and support for international facilities that are of strategic scientific, national security, and/or foreign policy interest to the United States. This mechanism would ideally complement funding from science agencies, make decisions based on substantial interagency input, and should allow for pooled funds to be operated at any agency with authorities to direct appropriated funds for use internationally to enable more collective action.
- ***Recommendation 8:*** Explore the creation of a mechanism under which assistance for S&T collaboration can be provided to international partners who otherwise lack scientific capacity. Partners may include nations that do not qualify for development assistance and/or lack existing STEM capacity to participate in research collaborations intended to be mutually beneficial.

Gap 3: Mission-driven scientific activity and foreign policy/national security interests must be more coordinated and balanced among Federal agencies to minimize siloes among development, national security, and research priorities.

There is an inherent tension within agencies between the need to focus on mission-driven activities and U.S. strategic foreign policy and national security objectives and needs.

U.S. government agencies are experienced and effective at international collaboration, but they need to be able to leverage this work for influence in U.S foreign policy and diplomacy. This would require

[88] European Commission. 2022. "Conclusion of Exploratory Talks on the Association of New Zealand and Canada to Horizon Europe: Towards Formal Negotiations." April 21, 2022. https://ec.europa.eu/info/news/conclusion-exploratory-talks-association-new-zealand-and-canada-horizon-europe-towards-formal-negotiations-2022-apr-21_fr.

[89] Matthews, David. 2022. "EU scopes out Horizon Europe association with Singapore." June 15, 2022. https://sciencebusiness.net/news/eu-scopes-out-horizon-europe-association-singapore.

[90] Montgomery, Kim and Gang Qin. 2021. "The Global Nature of Science, Technology and Innovation: An Interview with Ambassador Qin Gang, China's Ambassador to the U.S." https://www.sciencediplomacy.org/conversation/2021/global-nature-science-technology-and-innovation-interview-ambassador-qin-gang.

that ties between science agencies and diplomatic work be strengthened to avoid adding the relationship-building workload to science agencies. Enhancing coordination between U.S. S&T funding agencies and foreign policy/security agencies serves to both increase awareness of the risks associated with international cooperation, particularly around critical technologies,[91] and educate the security community on the impact of security measures on maintaining a dynamic S&T ecosystem.

At the same time, the high-level demand for quick-win bilateral S&T initiatives in the interest of diplomatic wins has detrimental effects on the ability of the DOS and science agencies to engage in long-term strategic planning and may negatively impact the implementation of domestic research programs. In some instances, science agencies have reported that program officers are overwhelmed by requests both from international partners and in support of U.S. diplomatic objectives, as international partners frequently wish to engage in individualized bilateral collaborative activities with the United States. The inability to respond to these requests may signal that the United States is disinterested in scientific partnerships with some of our key allies and partners, yet agency bandwidth to execute core missions which serve the American people must be preserved.

There are also significant constraints on the ability of the United States to be responsive to requests from foreign governments. Requests from foreign governments and a perceived need to include S&T in bilateral strategic dialogues limit the ability of both the DOS and science agencies to pursue longer-term strategic objectives in international R&D, and is often highly duplicative of activities pursued in other fora. If a collaboration requested by a foreign government does not align with a given agency's mission, the opportunity may be lost despite it being in the best interests of the United States to collaborate.

Requests from foreign governments for collaboration are highly focused on a small number of U.S. research institutions, often resulting in a misrepresentation of the broader U.S. scientific enterprise and creating missed opportunities for researchers – particularly those in Historically Black Colleges and Universities (HBCUs), other Minority-Serving Institutions (MSIs), and institutions in Established Program to Stimulate Competitive Research (EPSCoR) jurisdictions – to take advantage of the professional development and career acceleration opportunities afforded by international collaborations.

- ***Recommendation 9*****:** Expand detail opportunities between international offices in science and technical agencies to allow Federal experts to better familiarize themselves with international S&T practices and networks in other parts of the U.S. government.
- ***Recommendation 10*****:** Encourage amplification of existing international S&T collaboration efforts through public diplomacy, media outreach, and sustained people-to-people-level engagement.

Gap 4: The United States is likely underperforming in achieving DEIA goals in international S&T, which may be having a negative impact on U.S. competitiveness.[92]

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[91] Shyu, Heidi. 2022. "USD(R&E) Technology Vision for an Era of Competition." Official memorandum. Washington, D.C.: Department of Defense. https://www.cto.mil/wp-content/uploads/2022/02/usdre_strategic_vision_critical_tech_areas.pdf.

[92] The White House defined these terms as follows: *diversity* "means the practice of including the many communities, identities, races, ethnicities, backgrounds, abilities, cultures, and beliefs of the American people, including underserved communities"; *equity* "means the consistent and systematic fair, just, and impartial treatment of all individuals, including individuals who belong to underserved communities that have been denied such treatment"; *inclusion* "means the recognition, appreciation, and use of the talents and skills of employees of all backgrounds"; and *accessibility* "means the

The broader U.S. population is not well-represented in international scientific programs and exchanges at all levels, and likely is not experiencing equitable participation in international research collaborations.

As noted above, U.S. S&T leadership relies on a strong STEM workforce, yet the full breadth of American talent is not included in the U.S. S&T enterprise. Approximately 8% of STEM doctoral degree-earners in the United States in 2019 were Black/African-American, and a similar percentage were Hispanic; in 2019, the U.S. Census Bureau estimates that 12.8% of the U.S. population was Black/African-American and 18.4% was Hispanic.[93] Women make up only around one-third of the STEM workforce in the United States, and Blacks, Hispanics, and American Indians or Alaska Natives together represent 30% of the total workforce but only 23% of the STEM workforce.[94] Based on 2019 data, the United States ranks 17th globally and 15th among the 38 Organisation for Economic Cooperation and Development (OECD) countries[95] in researchers as a share of the workforce.[96]

Initiatives such as the Fulbright Program are known to have a positive impact on participants' careers, including their interest and their academic institution's interest in international engagement.[97] Underrepresented minority participation in the Fulbright Program has increased significantly in the past decade, rising by 62% for students and 40% for scholars.[98] However, data for the 2020-2021 class of U.S. Fulbright participants show that only 6% of both student and scholar participants were Black or African-American, and only 8% and 7% of students and scholars were Hispanic, respectively, reflecting the diversity of the broader applicant pool.[99]

Beyond the Fulbright data, data on the participation of underrepresented groups in international scientific collaborations are extremely limited. The data that exist are dated not encompassing, making it impossible to understand trends in participation. Based on data from 2006, only 27% of women in business, 23% of women in government, and 21% of women in educational institutions say they

design, construction, development, and maintenance of facilities, information and communication technology, programs, and services so that all people, including people with disabilities, can fully and independently use them." The White House. 2021. "Executive Order on Diversity, Equity, Inclusion, and Accessibility in the Federal Workforce." June 25, 2021. https://www.whitehouse.gov/briefing-room/presidential-actions/2021/06/25/executive-order-on-diversity-equity-inclusion-and-accessibility-in-the-federal-workforce/.

93 United States Census Bureau. No date. DP05 American Community Survey (ACS) Demographic and Housing Estimates for 2019. https://data.census.gov/cedsci/table?q=DP05&tid=ACSDP1Y2019.DP05.

94 National Science Board. 2022. "The State of U.S. Science and Engineering 2022, U.S. and Global STEM Education and Labor Force." https://ncses.nsf.gov/pubs/nsb20221/u-s-and-global-stem-education-and-labor-force.

95 The OECD countries are Australia, Austria, Belgium, Canada, Chile, Colombia, Costa Rica, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Japan, Republic of Korea, Latvia, Lithuania, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States. See: OECD. No date. "List of OECD Member countries - Ratification of the Convention on the OECD." https://www.oecd.org/about/document/ratification-oecd-convention.htm.

96 American Association for the Advancement of Science (AAAS). 2022. "U.S. R&D and Innovation in a Global Context: 2022 Data Update." https://www.aaas.org/sites/default/files/2022-05/AAAS%20Global%20R%26D%20Update%20May%202022.pdf.

97 A survey of Fulbright Scholars who participated in the program from 2005-2015 found that 68% of participants increased their involvement with international education at their home institutions; 50% reported that their institutions increased their support for international programming; and 36% of reported that their institutions increased their investments in dedicate more resources to implementing international programs. Fulbright Scholar Program. No date. "Global Impact and the Fulbright Effect". https://cies.org/global-impact-and-fulbright-effect.

98 The Fulbright U.S. Student Program accepts undergraduate and graduate applicants. The Fulbright U.S. Scholars program accepts academic faculty and other professionals. See https://us.fulbrightonline.org/ and https://fulbrightscholars.org/. For data on diversity and inclusion in both programs, see: Fulbright U.S. Student Program. 2020. "Fulbright Diversity and Inclusion Fact Sheet 2020-2021." October 1, 2020. https://us.fulbrightonline.org/uploads/files/diversity/Fulbright_DEI_Overview.pdf.

99 These percentages do not take into account participants who reported "Other" or did not report.

collaborate internationally, compared with 39% men in business, 29% men in government, and 28% men in educational institutions.[100] The subcommittee is unaware of any data that would allow us to better understand the degree to which there may be an underrepresented community gap in international research collaborations.

To address the issue of increasing representation in international STEM opportunities, the United States should leverage HBCUs, other MSIs, and institutions in EPSCoR jurisdictions in international S&T collaborations. Greater involvement of these institutions creates opportunities for the United States to accelerate its own research enterprise: by not having equal participation in international engagement, the United States is missing out on having all of its STEM talent contributing to national S&T advancement at a time when U.S. competitiveness internationally is a concern. Further, the high demand for partnerships with a limited subset of institutions in the U.S. research enterprise limits the visibility and availability of underrepresented institutions that may be eager and willing to engage with international partners. The underrepresentation of these institutions and a lack of underserved community involvement in international S&T efforts creates additional bandwidth constraints on the ability of the United States to be responsive to requests for international partnerships.

- ***Recommendation 11*****:** Explore mechanisms to support exchange visitor programs with HBCUs, other MSIs, and institutions in EPSCoR jurisdictions, as well as training and development programs at all educational levels that may increase the capacity of interested institutions to more readily engage with international partners.
- ***Recommendation 12*****:** Explore how researchers in both STEM and non-STEM fields at HBCUs, other MSIs, and institutions in EPSCoR jurisdictions are participating in international S&T collaborations, including as reflected in co-authored publications. Assess whether and how international engagement can act as a career accelerator for researchers and students from underrepresented groups and if additional mechanisms may be needed to positively impact representation in international S&T settings.

Gap 5: The legal requirement that F-1 or J-1 visa holders change their visa class or immigration status at the end of their studies if they wish to remain in the United States may serve to exclude foreign talent.

While there is a stated U.S. policy interest in attracting and retaining STEM talent in the United States, STEM students applying for an F-1 or J-1 U.S. visa must overcome the presumption of immigrant intent laid out in the Immigration and Nationality Act (INA) to be eligible for a student visa. This means that at the time of the applicant's interview they must have the stated intention of departing the United States at the end of their studies or work to qualify for a U.S. visa and must be able to document permanent ties to their home country that supports this intention. This prohibition, which inhibits the stated U.S. policy goal of retaining foreign STEM talent, would require an act of Congress to change.

Research shows the regulatory process surrounding F-1 and J-1 student visas applicants may reduce foreign students' desire to study in the United States.[101] F-1 visa holders are permitted up to 12 months of optional practical training (OPT) after graduating, and students with STEM degrees may extend their

[100] Zippel, Kathrin. 2017. *Women in Global Science: Advancing Academic Careers through International Collaboration*. Stanford: Stanford University Press. Data are based on the National Science and Engineering Indicators from 2006.

[101] Lami, S. 2017. "Challenges and New Requirements for International Mega-Science Collaborations." https://www.sciencediplomacy.org/article/2017/mega-science-collaborations.

OPT period for up to 24 additional months. [102] After the OPT period ends, another visa class or a change in immigration status must be secured to remain in the United States.

Updates to U.S visa policy in the past two years have focused on clarifying and expanding avenues for foreign talent to come to the United States by: extending the duration of academic training in STEM fields under the J-1 visa by 18 months, up to 36 months in total; clarifying procedures around O-1A "extraordinary ability" visas and national interest waivers for advanced degree holders in STEM fields;[103] and increasing the number of fields of study included under the OPT program. [104]

Although the United States is making improvements, other countries offer greater opportunity for foreign STEM talent to remain in their countries at the end of their studies. For example, Germany allows international students to live in Germany for up to 18 months after their graduation to find a job and offers students permanent residency after two years of post-graduation employment.[105] Australia allows engineering graduates at any education level to remain up to 18 months post-graduation.[106]

Gap 6: Federal science agencies do not prioritize staffing for international collaborations and the U.S. government could do more to retain scientists who are trained in diplomacy.

Staffing for Department- and Agency-wide international S&T offices seldom meets demands for international partnerships and participation in international fora, impacting the ability of the United States to respond to increasing demands bilaterally and multi-laterally from allies and partners as well as the acknowledged need for the U.S. government to more actively be involved in international organizations and standards-setting bodies in order to counter strategic competitors. While U.S. officials participating in these bodies are often from technical rather than international offices, this type of work generally is not their primary responsibility in their offices.

The job series that help facilitate getting specific skillsets into the U.S. government are poorly aligned with the realities of scientific education, creating unnecessary bureaucratic hurdles that prevent desired candidates from being able to qualify for permanent positions by not valuing their technical expertise and/or background. The result of this is that agencies are often forced to hire otherwise qualified talent as contractors to avoid losing subject matter expertise, limiting the ability of such individuals to represent the United States abroad or to contribute to interagency activities

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[102] U.S. Citizenship and Immigration Services. 2022. "Optional Practical Training (OPT) for F-1 Students." May 18, 2022. https://www.uscis.gov/working-in-the-united-states/students-and-exchange-visitors/optional-practical-training-opt-for-f-1-students.

[103] A national interest waiver allows an immigrant of exceptional ability to petition for themselves without needing a job offer from an employer to support their application. See: U.S. Citizenship and Immigration Services. 2022. "Chapter 5 – Advanced Degree or Exceptional Ability." June 10, 2022. https://www.uscis.gov/policy-manual/volume-6-part-f-chapter-5.

[104] White House. 2022. "FACT SHEET: Biden-Harris Administration Actions to Attract STEM Talent and Strengthen our Economy and Competitiveness." https://www.whitehouse.gov/briefing-room/statements-releases/2022/01/21/fact-sheet-biden-harris-administration-actions-to-attract-stem-talent-and-strengthen-our-economy-and-competitiveness/.

[105] Hoffmeyer-Zlotnik, P. Grote, J. 2019. "Attracting and retaining international students in Germany. Study by the German National Contact Point for the European Migration Network (EMN). Working Paper 85 of the Research Centre of the Federal Office for Migration and Refugees, Nuremberg: Federal Office for Migration and Refugees." https://www.bamf.de/SharedDocs/Anlagen/EN/EMN/Studien/wp85-internationale-studierende.pdf?__blob=publicationFile&v=20.

[106] Australian Government, Department of Home Affairs. N.d. "Skilled—Recognised Graduate visa". https://immi.homeaffairs.gov.au/visas/getting-a-visa/visa-listing/skilled-recognition-graduate-476#About.

domestically. Given the increasing role of science and technical skills relevant for foreign diplomacy and science diplomacy, it is crucial to ensure that unnecessary 20th-century bureaucratic hurdles do not block the development of a 21st century workforce.

U.S. government experts often do not have incentives to contribute to international S&T efforts, and they are sometimes disincentivized from doing this work. For example, experts involved in standards-setting bodies and other international working groups are often required to do so in addition to and above their primary duties, limiting their ability to develop the types of professional skills and diplomatic awareness necessary to be successful at pursuing U.S. research or strategic objectives at their agencies and on behalf of the United States.

- ***Recommendation 13*****:** Critically review existing job series and consider new series that would allow the recruitment of technical professionals within agencies to support S&T diplomacy and enhance the government's ability to recruit skilled and specialized representation for highly technical international activities, including standards-setting bodies and international technical working groups.
- ***Recommendation 14*****:** Explore the creation of mechanisms within the U.S. government that mobilize and train Federal scientists to communicate effectively to non-scientist decision makers within the U.S. government and abroad.
- ***Recommendation 15*****:** Consider providing incentives and training opportunities to experts who contribute to international standards-setting bodies and other relevant international working groups to ensure that the appropriate technical experts are active contributors to these discussions.

Gap 7: Science and Technology Agreements (STAs) are good tools for research-performing agencies to accelerate collaborative activities, but they may raise funding or bilateral engagement expectations that the United States is unable to fulfill.

STAs provide a high-level signal to partner governments of the intent of the United States to launch S&T collaborations with a partner government and expedite and ease the negotiation of implementing arrangements, memoranda of understanding (MOUs), or other cooperation instruments around challenging topics such as intellectual property, data and information sharing, personnel or equipment exchanges, and material transfers. STAs can also promote shared understanding of values underpinning joint collaboration, provide regular opportunities to convene with partner countries to discuss vital S&T policy topics, and more broadly enhance bilateral relationships.

On the other hand, STAs often create obligations for the United States to meet periodically with international partners to coordinate bilateral activities, and they can create unrealistic expectations of joint projects or ongoing agency engagement if not managed carefully. Likewise, STAs are unable to provide meaningful changes in U.S. customs or border policy that might accelerate exchanges on U.S. priority projects. This means that such agreements are not able to directly provide enhanced and reciprocal access to resources for U.S. private sector or academic interests in countries with whom the United States has an STA. Additional legal authorities to provide enhanced access to U.S. labs for close allies and partners could reinvigorate scientific collaborations in areas where reduced interaction has served to inhibit cooperation.

The administrative workload associated with maintaining commitments under these STAs, consequently, leads to a greater prioritization of effort toward high-income countries over LMICs and an emphasis on large-scale projects and activities. For example, the United States only has one bilateral STA in Sub-Saharan Africa (South Africa).

- ***Recommendation 16*****:** Assess current STAs for relevancy and gaps with a view to addressing with foreign partners as and when appropriate. Evaluate mechanisms for the United States to increase data and facility access, scientific exchange, and visa or customs and border flexibilities for visitors from private sector and academic institutions in connection with STAs or related agreements. These mechanisms would provide benefits beyond direct bilateral initiatives and create more opportunities for the broader S&T community to promote academic, research, and idea exchange with allies and emerging science partners. Such flexibilities could also extend their utility in partnerships with LMICs and increase the ability of such agreements to serve as a motivator for international scientific partnerships.

Looking Forward

The world faces many complex challenges in 2022, such as recovering from and adapting to the ongoing COVID-19 global pandemic and addressing the widespread impacts of climate change, including developing and implementing mitigation efforts. The United States can make vital contributions to address these global issues both via technical knowledge and expertise and by using science engagement to help build relationships internationally. An empowered S&T enterprise will elevate the United States as the partner of choice internationally, lead to economic growth, and drive and foster ambitious S&T efforts that address the most pressing global issues. An invigorated Federal workforce that is focused and empowered to carry out and advance international S&T engagements and partnerships will extend U.S. influence worldwide. Domestic and international STEM talent will see the United States as the first-choice destination for education and S&T careers, further advancing U.S. scientific, technological, and economic growth. To maintain U.S. S&T leadership in an increasingly competitive S&T environment, the United States needs to ambitiously advance international research or risk losing influence.