AMERICAN ACADEMY
OF ARTS & SCIENCES

Global Connections

Emerging Science Partners

A REPORT FROM THE **CHALLENGES FOR INTERNATIONAL SCIENTIFIC PARTNERSHIPS INITIATIVE**

> "Getting enough energy to satisfy the needs of the developing world without bringing on an eco-disaster is not going to be easy. It will require a marriage of science and technology with good international policy, something that is always hard to bring off. We need to get it right this time.
>
> *— Burton Richter*

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AMERICAN ACADEMY OF ARTS & SCIENCES
Cambridge, Massachusetts

ISBN: 0-87724-146-5

This publication is available online at www.amacad.org/project/CISP.

Suggested citation: American Academy of Arts and Sciences, *Global Connections: Emerging Science Partners* (Cambridge, Mass.: American Academy of Arts and Sciences, 2022).

COVER PHOTO CREDIT
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From the President of the American Academy

The United States is the world's largest funder of scientific research in an increasingly global science and technology (S&T) enterprise. It has a key leadership role to play in shaping scientific research to ensure that breakthroughs can help address our many global challenges. This need applies both to tackling issues with urgent scientific questions, such as those that arise when combating climate change and pandemics, and to building a more robust, more equitable scientific enterprise that leverages the power of innovation to benefit all people and create a more prosperous and just world.

As scientific leaders in the United States continue to reflect on the nation's significant contributions to science in the years since the end of World War II and consider the promise of what the next generation will hold, it is worth expanding the historical lens of S&T investment. Indeed, the global system of scientific research is dynamic, with various countries playing diverse leadership roles. Increasingly, countries outside of the United States are boosting their national scientific funding, further spreading talent and research capacities worldwide. The way that science is conducted is likely to change significantly in the decades to come. U.S. policy-makers must take these trends into account to position the country to participate fully and lead innovation for future generations.

Although national funding levels and institutional scientific capacities are varied, science as a practice knows no national boundaries, and scientific talent can arise anywhere. Countries and researchers with limited financial resources today may provide the leading scientific talent of tomorrow. The scientific enterprise, historically an exclusionary practice reserved for the most privileged among us, will benefit from a substantial expansion of participation in research both within and beyond our borders. Emerging science partners are key collaborators for the United States in tackling global challenges and making discoveries that will improve all lives. This report lays out the case for collaborating with countries actively building their scientific capacity, examines key entry points and strategies for engagement, and puts forth recommendations for making these partnerships more robust and equitable, with specific mechanisms proposed for select U.S. audiences.

The United States has an important leadership role to play in engaging with these emerging science partners and in building up scientific research capacity for the benefit of all. Indeed, as research becomes increasingly global, for the United States to conduct world-class research, U.S. scientists must engage on a global scale with their peers, wherever they may be located. As underscored by the ongoing COVID-19 pandemic and the escalating climate crisis, the United States will benefit by working closely with established and emerging science partners alike to tackle the challenges facing the world.

This report is the final one of the Academy's Challenges for International Scientific Partnerships (CISP) initiative and joins *America and the International Future of Science* (Winter 2020) and *Bold Ambition: International Large-Scale Science* (Spring 2021) in the analysis of the challenges and benefits of American participation in international scientific partnerships. The project, established in 2017 under the initiative of then-Academy President Jonathan F. Fanton, identifies mechanisms by which the United States could become a better partner in international collaborations of all scales and across all disciplines. It is a pleasure to continue this important work throughout my tenure as Academy President.

In this effort, the Academy extends its sincere gratitude to the cochairs of the Emerging Science Partners Working Group: **Shirley Malcom**, Senior Advisor and Director of SEA Change at the American Association for the Advancement of Science, and **Olufunmilayo Olopade**, Walter L. Palmer Distinguished Service Professor in the Biological Sciences Division, Professor of Medicine & Human Genetics, and Associate Dean for Global Health at the University of Chicago. In addition, we are grateful for the continued leadership of CISP Cochairs **Arthur Bienenstock**, Professor Emeritus of Photon Science, Special Assistant to the President for Federal Research Policy, and Associate Director of the Wallenberg Research Link at Stanford University, and **Peter Michelson**, Luke Blossom Professor in the School of Humanities and Sciences, Professor of Physics, and Senior Associate Dean for the Natural Sciences at Stanford University.

The leadership and guidance from the CISP Steering Committee and the working group on Emerging Science Partners (ESP) were invaluable for the development of this report and in ensuring essential perspectives and voices were heard throughout this work. I am grateful to the Academy's Board of Directors, Council, and Trust for their support of the development of this initiative, along with the contributions of many Academy Fellows. I especially extend my thanks to the scientists and policy-makers from all corners of the world who participated in the regional soundings and events hosted by this initiative and shared their perspectives on changes that would substantially shift U.S.-ESP collaborations toward strong, equitable partnership. Finally, this initiative has been graciously supported with funding from the Alfred P. Sloan, William and Flora Hewlett, and Gordon and Betty Moore Foundations, for which we are sincerely appreciative.

I also thank the Academy staff who helped prepare this report: Rebecca Tiernan, Amanda Vernon, Islam Qasem, Tania Munz, Phyllis Bendell, Heather Struntz, Peter Walton, and Scott Raymond.

I join with all of those who supported the development of this report's findings to call for its uptake by America's scientific and policy leaders. As we look ahead to future challenges and opportunities for science and innovation, our country must fully participate in all scientific endeavors, including collaborations with talent in all parts of the world, and promote a just and equitable society.

Sincerely,
David W. Oxtoby
President, American Academy of Arts and Sciences

Project **Takeaways**

Challenges for International Scientific Partnerships (CISP) is an American Academy initiative to identify the benefits of international collaboration and recommend actions to be taken to address the most pressing challenges facing these partnerships. This project has concluded that:

1. The United States should support and expand international scientific collaborations, including with nations with which the United States has strained relations, such as China. Any restrictions on international collaborations involving federally supported research should be well-justified and carefully and narrowly defined.[1]

- Participation in international scientific collaborations is beneficial not only for U.S. science, but for the United States overall.
    - International scientific collaborations complement and contribute to a strong domestic R&D enterprise and strengthen U.S. economic competitiveness and national security.
    - To perform state-of-the-art science and address global challenges effectively, U.S. scientists must continue to engage with the global scientific community.

2. International large-scale scientific endeavors are an important component of our nation's overall science and technology enterprise. The United States must be prepared to participate in international large-scale science partnerships and work to ensure their success, including contributing support for operations outside the United States.[2]

- Some future large-scale science endeavors will be on a global scale and will necessarily involve international cooperation, with some international efforts and facilities sited outside of the United States but requiring U.S. support.
- Large-scale research instrumentation and facilities are essential for scientific advancement across a variety of disciplines and will become increasingly difficult for the United States to fund unilaterally.

3. Emerging science partners around the world are and will continue to be important scientific collaborators. The United States should broaden and deepen scientific collaboration with them.

- Scientific talent arises around the globe at an increasing rate as many countries invest in building a more robust S&T enterprise.
- Many of the most pressing scientific questions are not defined by national boundaries and require global collaboration for advancement.

Prologue

Challenges for International Scientific Partnerships (CISP) is an American Academy initiative that aims to articulate the benefits of international collaboration and recommend solutions to the most pressing challenges associated with the design and operation of partnerships. This initiative, funded by the Alfred P. Sloan, William and Flora Hewlett, and Gordon and Betty Moore Foundations, seeks to identify policy recommendations and best practices to mitigate challenges for international science collaborations, including physical facilities, distributed networks, and peer-to-peer partnerships. The project is cochaired by **Arthur Bienenstock** (Stanford University) and **Peter Michelson** (Stanford University).

The **Emerging Science Partners** (ESP) working group explores the importance of U.S. partnerships with ESPs and the issues particular to U.S. scientific collaborations at all scales with countries seeking to boost their scientific capacity, particularly those with limited resources to do so. This working group frames discussions around how the United States can be a better collaborator in its partnerships with emerging science partner countries and work to increase equity in these collaborations. The ESP working group is cochaired by **Shirley Malcom** (American Association for the Advancement of Science) and **Olufunmilayo Olopade** (University of Chicago).

The **Large-Scale Science** (LSS) working group approaches international collaborations through the lens of issues particular to large-scale science and not peer-to-peer or small-scale international work. This group has been tasked with exploring how the United States can enhance its role in these partnerships, both in physical facilities (e.g., the European Organization for Nuclear Research, CERN) and distributed networks (e.g., the Human Cell Atlas). The group is focusing on recommendations that will bolster U.S. ability to partake in large-scale collaboration efforts as a meaningfully engaged partner. The LSS working group is led by CISP cochairs **Arthur Bienenstock** and **Peter Michelson**.

This report, *Global Connections: Emerging Science Partners*, describes the importance of strengthening collaborations between the United States and emerging science partner countries. It provides a series of recommendations for both strengthening these partnerships and making them more equitable. The project has also released two other reports: *America and the International Future of Science*, on the importance of international scientific collaboration at all scales, and *Bold Ambition: International Large-Scale Science*, on best practices for building large-scale scientific collaborations in the future.

Executive **Summary**

The American Academy of Arts and Sciences' initiative on Challenges for International Scientific Partnerships (CISP) was formed to assess where international collaborations are key for U.S. interests and to identify solutions to the challenges they face. This initiative has taken a broad view of international scientific collaboration as extending across scientific disciplines and scales and as encompassing all regions of the globe. As scientists raise the alarm on risks from a warming planet and the COVID-19 pandemic continues to impact lives and economies, this initiative has become only more convinced that a coordinated, collaborative science and technology (S&T) enterprise is essential to address the global challenges facing all of us. Key imperatives for international collaboration are presented in the initiative's first report, *America and the International Future of Science*, while principles for successful international collaboration on large-scale initiatives are presented in the subsequent report, *Bold Ambition: International Large-Scale Science*.

Global Connections: Emerging Science Partners focuses on scientific partnerships between scientists in the United States and scientists in countries with emerging scientific enterprises. These countries are largely classified as Low- and Middle-Income Countries (LMICs) and Least-Developed Countries (LDCs) based in the Global South, including in sub-Saharan Africa, Latin America and the Caribbean, Asia and the Pacific, and the Middle East and North Africa. Of particular focus in this report are countries that have been identified by The World Academy of Sciences as "S&T Lagging"[3] and are specifically seeking to boost science capacity for development.

As emphasized in the initiative's earlier reports, two interlinked characteristics of the U.S. scientific community have contributed significantly to the nation's scientific and technological leadership. First, its universities have attracted some of the world's most capable students to graduate and postdoctoral studies. Second, its researchers have formed collaborations with talented scientists and engineers around the world.

Some international students educated here have returned to their home countries to play important roles in advancing S&T enterprises there. While many international students choose to remain in the United States, contributing to the nation's scientific and technological preeminence, they also often collaborate with researchers in their home countries, who frequently possess unique knowledge, capabilities, or situations that make outstanding research possible and enable important new discoveries. The resulting circulation of scientific talent, knowledge, and ideas has been a win-win situation for both the United States and the students' countries of origin.

Significant changes are or will soon be underway that the United States must consider. The global research community is expanding and becoming more interdependent as it explores complex scientific questions and confronts major global challenges. At the same time, as the link between national prosperity and scientific capacity becomes increasingly apparent, international competition to attract the brightest students and young talent is increasing. These developments, coupled with policy changes in the United States and abroad, may lead to a significant decrease in the number of international students coming here to study—at a time when the country is struggling to build and sustain a robust and diverse domestic workforce in the science, technology, engineering, and mathematics (STEM) fields.

Today's emerging science partners (ESPs) hold the same promise as did countries like China, India, and South Korea just decades ago and they are projected to have a major and steadily increasing fraction of the world's next generation of young talent. As scientific research becomes increasingly global, partnerships with scientists from around the world, including ESPs, will be key to unlocking future scientific discovery in all disciplines. The U.S. S&T enterprise should incorporate into its short- and long-term planning strategies for engagement with ESPs. Policies are needed that will build a stronger S&T enterprise for the world and contribute to sustaining a leadership role for the United States in tackling global challenges and uncovering new knowledge.

Collaborations between the United States and ESPs need to be based on mutual commitments to high-quality science, rooted in shared goals and scientific priorities, be mutually beneficial to all collaborators, and reflect the U.S. commitment to transparency, equity, and openness. As the CISP initiative held workshops with ESP researchers, issues of a lack of equity or fairness in scientific collaborations commonly arose, including the need to support the involvement of women and early career scientists. The United States needs to recognize and respect the merit and valuable perspectives researchers in ESPs bring to the table and the realities of available resources. Both partners must address concerns of equity and fairness upfront if sustainable, long-term collaborations are to be successfully built.

ESPs are, increasingly, a key set of collaborators with whom the United States should deepen engagement. The CISP initiative has identified four key imperatives that underlie why the United States should continue to build and strengthen collaborations with ESPs. These imperatives are:

1. Scientific Advancement and Addressing Global Challenges

Scientific advancement to expand the frontiers of science and address pressing global challenges, such as climate change and pandemics, requires international collaboration. ESPs can play important roles in achieving these advancements as their capacities grow stronger. The United States must demonstrate and maintain its leadership role through strengthening partnerships with ESP scientists to solve problems and stimulate innovation. Addressing global challenges is dependent on both broad-based research as well as research at scales accounting for unique local contexts.

2. Strengthening Global S&T Capacity and the Global STEM Workforce

Every nation contributes to and shares the strengths and weaknesses of the global research community. This is particularly true as we confront global challenges. The United States has a critical role to play in strengthening the global community through its own partnerships with ESPs, including the advanced education of ESP students, collaborative research, and building sustainable infrastructure. Education and research partnerships not only strengthen the global community, but they enhance the U.S. national S&T enterprise.

3. Global Understanding and Science Diplomacy

It is essential to partner with ESPs to enhance global understanding and strengthen science diplomacy. Scientific research is an endeavor built on shared values of merit, transparency, and openness. Research collaborations provide a mechanism for strengthening understanding of cultural differences and varied national and regional priorities. Science can often open channels that have been blocked because of political, economic, or social differences.

4. U.S. Leadership

As future global S&T evolves, it is important that the United States maintain its leadership role, contributing to the development of capacity worldwide and engaging with emerging and established partners. The United States cannot afford to allow its collaborations with ESPs to stagnate or diminish as these scientific communities grow stronger and even more critical to the global research community.

Driven by these imperatives, the report makes the following recommendations:

1. The United States should actively foster and build collaborations with ESPs, including by welcoming ESP researchers, particularly those seeking graduate education, to U.S. universities and research institutes.

2. Through its research and education collaborations with ESPs, the United States will and needs to contribute to building global research capacity and the global STEM workforce.

3. Collaborations with ESPs should reflect the values of transparency and equity.

Moving forward on these recommendations would strengthen and expand partnerships with ESPs through sustained long-term commitments across disciplines and scales. Given the diverse ecosystem of S&T in the United States and in ESPs, opportunities for sustained collaboration are numerous. These include partnerships across and among government agencies, universities, research institutes, centers of excellence, scientific societies and academies, foundations and philanthropies, and the private sector.

Policy and program actions are needed if U.S.-ESP partnerships are to be adequately strengthened and if they are to be made more equitable. This report puts forth specific mechanisms for doing so to the four key U.S. audiences with substantial engagement with ESPs: 1) federal agencies; 2) universities and research institutes; 3) scientific societies and academies; and 4) foundations and the private sector (see Mechanisms on page 39).

These mechanisms have been identified by the CISP initiative through discussions with the key audiences mentioned above and in partnership with scientists based in ESP countries from all regions of the world and representing diverse disciplines, personal backgrounds, and career stages. They are the product of an effort to identify actions rooted in the priorities of both the U.S. S&T enterprise and those of ESPs seeking to build strong and equitable international scientific collaborations.

Introduction

In the 1980s, Colombian physician Francisco Lopera and nurse Lucía Madrigal noticed an alarming pattern in Medellín: families whose members developed severe memory loss in their forties.[4] They published their intriguing findings but struggled to gain traction in the global scientific community until Kenneth Kosik, a U.S.-based neuroscientist, traveled to Colombia to give a talk on Alzheimer's disease in Bogotá. Lopera attended this seminar and, following the talk, he approached Kosik to share his own findings.[5] Thus began a scientific collaboration that discovered the E280A presenilin genetic mutation, the most common cause of familial early onset Alzheimer's.[6]

This work was directly supported by grants from the National Institutes of Health (NIH), specifically the National Institute on Aging and the Fogarty International Center (FIC). Building from a foundation of trust among patients and researchers in the region, Lopera and his collaborators identified five thousand patients from twenty-five families who have early onset Alzheimer's disease. They share a genetic mutation first brought to the region by a Spanish colonist in the 1500s.[7] By identifying families genetically destined to develop early onset Alzheimer's disease, this collaboration generated a unique opportunity for research into preventing the disease. The first prevention trial for Alzheimer's disease is currently being conducted by the U.S. pharmaceutical company Genentech, a subsidiary of the Swiss company Roche, in both this Colombian population and with U.S. participants as a part of the U.S. Alzheimer's Prevention Initiative.[8]

Many U.S. collaborators are working with this Colombian population to better understand the biology of Alzheimer's disease. The Multicultural Alzheimer's Prevention Program at Massachusetts General Hospital is directed by Yakeel Quiroz-Gaviria, a Colombian native, and has already begun a longitudinal biomarker study in its COLBOS (Colombia-Boston) project. Participants undergo initial scanning and testing with Lopera at the University of Antioquia in Medellín and then travel to Boston for additional neuroimaging.[9] Among other findings, the collaboration has discovered brain pathology well before clinical onset, generating hopes that biomarkers and preventive therapeutics may unlock improved treatment for Alzheimer's disease.[10]

This story is a key part of the larger race to cure Alzheimer's disease for those suffering from its debilitating effects, including an estimated six million Americans.[11] It is one of many examples that demonstrates the essential role that scientific collaborations with countries that are emerging science partners (ESPs) play in the American research and development

(R&D) enterprise (see Emerging Science Partners, ESPs, on page 5).

Publication trends indicate the global recognition of the importance of international collaboration. Between 2010 and 2020, the percentage of internationally coauthored science and engineering (S&E) publications increased from 18 percent to 23 percent; authors based at U.S. institutions had the greatest participation, with authorship on approximately 35 percent of all internationally coauthored publications in 2020.[12] While most U.S. collaborations with international partners continue to be with established scientific enterprises in countries such as China and the United Kingdom, the United States is a top collaborator with many emerging scientific enterprises as well, including in Colombia, South Africa, and Thailand.[13] International scientific collaborations are critical endeavors that drive innovation and boost prosperity in all parts of the world and should include ESPs, as scientific talent is a resource that all nations possess.[14]

Engagement of the U.S. scientific community with ESPs is essential if the United States is to continue to have a leadership role in pushing the frontiers of scientific discovery, addressing global challenges, and building the global science and technology enterprise. Scientific capacity will grow in the United States and ESPs alike, and scientific advances will proceed more effectively. Moreover, international understanding and relationships across cultures and nationalities will be bolstered.

U.S. support for collaborations with ESPs is provided by a range of federal agencies and programs and nongovernmental funders, each with its own specific authorities and requirements. The United States also supports ESPs through its membership in and support of the United Nations (UN) and other international organizations. In the face of current global challenges, it would benefit the United States to revisit and reevaluate some of its policies and requirements for allocating funding to international researchers and research programs.

Francisco Lopera, a behavioral neurologist at the University of Antioquia in Medellín, leads a team of researchers studying a local family with a genetic mutation that causes early onset Alzheimer's disease. Photo © by Getty Images/Steve Russell.

As the United States builds scientific collaborations, including in evolving and emerging fields of science, numerous challenges must be addressed, such as differing research priorities and approaches, mismatches in capacity, and historical inequities. Addressing these issues requires changes in policy, program design, and implementation across the scientific community and a range of stakeholders.

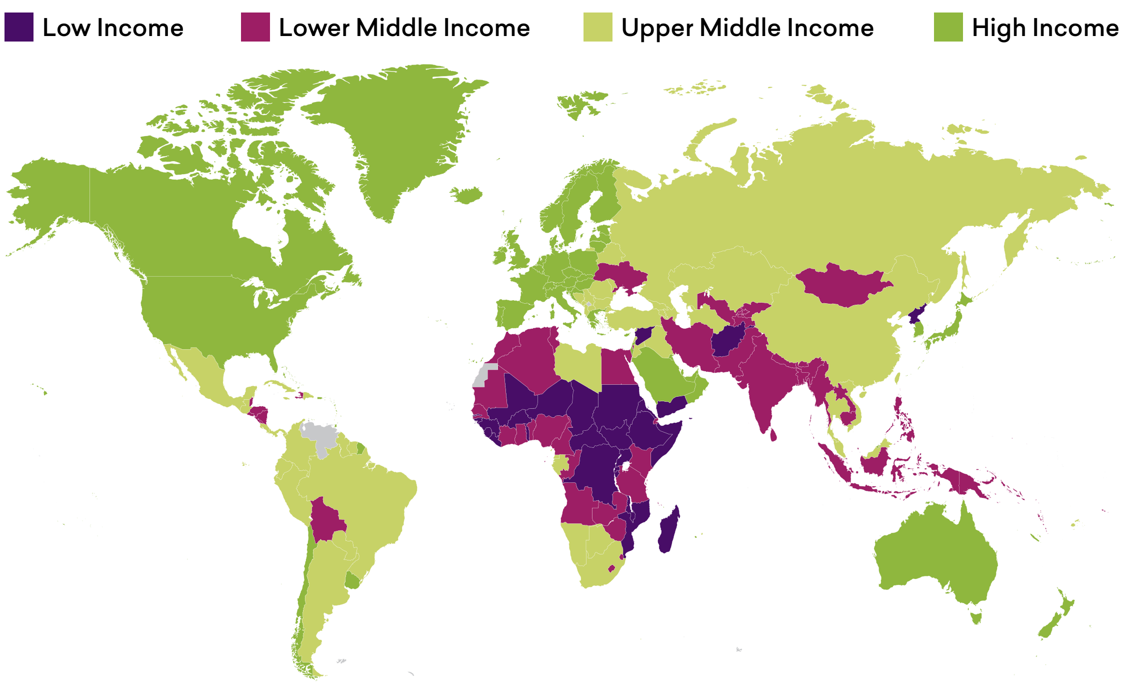
This report demonstrates the importance of these collaborations to the United States, explores the challenges they face, and concludes that the United States should actively foster and build collaborations with ESPs, paying careful attention to issues of equity in these partnerships, especially surrounding issues of gender parity (see Recommendations on page 39).

Defining ESPs

This report uses the term *emerging science partners* (ESPs) to refer to a subset of countries and the researchers within them. ESPs are actively seeking to build their own science capacities to be consistent with those of the Global North and more recently industrialized countries such as Brazil, China, India, Mexico, and South Africa.

ESPs include countries identified as "least-developed countries" (LDCs) by the UN and as "low- and middle-income countries" (LMICs) as defined by the World Bank. The Academy's Challenges for International Scientific Partnerships (CISP) ESP working group has a particular focus on nations identified by The World Academy of Sciences (TWAS) as

Countries by Income Level



Source: World Bank Development Indicators, "The World by Income and Region," World Bank, https://datatopics.worldbank.org/world-development-indicators/the-world-by-income-and-region.html.[15] Map image © by Free Vector Map.

S&T-lagging countries with capacity-building needs. These countries are in the Global South, in sub-Saharan Africa, Latin America and the Caribbean, Asia and the Pacific, and in the Middle East and North Africa.

The concept of an "emerging" science partner is intrinsically in flux as individual countries shift economically and adjust their investments in S&T. Countries that could be considered ESPs as of the publication of this report may no longer be considered "emerging" as their science capacities expand. This report focuses on the benefits to the United States of strengthening partnerships with countries that are on an emergent trajectory because of their potential for scientific excellence, especially if their domestic funding and support for science research are increasing. Partnerships like these have historically been valuable for the United States. South Korea and China, two countries that would have been considered ESPs in the not-too-distant past, are two of the top U.S. scientific collaborators today. In 2020, China was the top collaborator with the United States on scientific publications (26.28 percent); South Korea was also a significant partner (4.50 percent).[16] Notably, South Korea ranked second globally in 2019 for percentage of gross domestic product (GDP) investment in R&D (4.64 percent; the United States' and China's percentage of GDP investment in R&D were lower at 3.07 percent and 2.24 percent, respectively).[17]

While this report focuses on partnerships with ESPs, and the recommendations are primarily intended to foster and strengthen such collaborations, many of the perspectives addressed in the report echo the initiative's earlier reports on international science cooperation, which hold lessons and suggestions for strengthening partnerships and building equity into scientific research more broadly, both in international and national collaborations.

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Defining Partnerships

Research partnerships with ESPs can take a multitude of forms, including peer-to-peer collaborations, formal large-scale scientific collaborations that include ESP members (e.g., CGIAR; Human Hereditary and Health in Africa, or H3Africa; and MeerKAT), and partnerships focused on economic development or capacity building (e.g., research programs through the United States Agency for International Development [USAID] and the African Science Academy Development Initiative [ASADI]). This report takes a broad view of collaboration, and its findings are relevant across scales and types of collaboration and across scientific disciplines.

Imperatives for Collaboration with Emerging Science Partners

The CISP initiative's report *America and the International Future of Science* discussed the critical importance of U.S. engagement in international scientific partnerships. Such engagement is valuable for our nation's scientific enterprise and for achieving broader goals of national security and economic competitiveness.[18] Partnerships with ESPs are an important element of this effort. ESPs represent a critical component of the world's global S&T community.

Partnerships with ESPs are imperative for several key reasons, including:

- promoting scientific advancements, including addressing global challenges;
- strengthening global S&T capacity and the global science, technology, engineering, and mathematics (STEM) workforce;
- enhancing global understanding and science diplomacy; and
- contributing to maintaining the U.S. leadership role in the global research community.

Scientific Advancement and Global Challenges

Advancements in all scientific fields will enable scientists to unlock groundbreaking discoveries. ESPs are essential partners in these endeavors, from addressing global challenges that span international borders to participation in large-scale science initiatives.

Global Challenges

A comprehensive worldwide effort and increased investment in S&T will be necessary to address global challenges in the years ahead, and ESPs will be important partners with whom the United States should increasingly engage. Two key challenges that we now face are: 1) climate change and overall environmental degradation; and 2) emerging infectious diseases with the potential to cause pandemics.

Climate Change

Climate change is affecting and will continue to affect many aspects of societies across national boundaries. Desertification and deforestation may have increasingly dangerous consequences for food and water security, biodiversity loss, and ecosystem services.[19] Extreme weather events, from hurricanes to droughts to wildfires, will decimate communities and impact resource availability, potentially leading to forced displacement and implications for already tense border spaces, such as the U.S.-Mexico border.[20] Indeed, some scientists suggest climate change and the worsening drought in the Middle East are in some part responsible for the ongoing devastating Syrian war and refugee crisis in Europe.[21] The many cascading impacts of climate change will be felt most strongly by the least-developed countries and the world's most vulnerable groups, including women and girls.[22]

In August 2021, the UN Intergovernmental Panel on Climate Change (IPCC) released its sixth assessment report, which concludes that many of the climate changes we are witnessing today are irreversible in the next hundreds to thousands of years and that significant action will be required to limit further warming and extreme outcomes.[23] The developed nations are disproportionately responsible for the levels of greenhouse gases (GHGs) emitted annually and for historical emissions. The top three emitters of GHGs (China, the United States, and the collective countries of the European Union) accounted for approximately 41.5 percent of emissions annually in 2018, whereas the bottom one hundred emitters, primarily LMICs and LDCs, accounted for only 3.6 percent.[24]

China, currently the largest national emitter of GHGs in the world, has a noticeable influence on green energy investment. Declining investment in green technology in China in 2019 was among the factors that discouraged further investment in other parts of the world.[25] The growing influence of China's massive global development initiatives could contribute to increasing emissions and escalating climate change. China's Belt and Road Initiative (BRI), in particular, has raised concern for its associated environmental risks, especially with its transportation projects.[26] Notably, China recently announced that it would stop construction of coal-burning power plants abroad.[27]

The developing nations of the world, including many ESPs, contribute far less to GHG emissions, but they often face the brunt of the environmental and societal consequences of a changing climate.[28] In many ways, this vulnerability has forced them to be at the helm of finding ways to continue industrializing while maintaining low emissions. Guided by the UN's sustainable development goals (SDGs), many ESPs are actively working to invest in greener technologies and strategies to build their economies.[29] In particular, leapfrog technologies could enable sustainable development and solutions as ESPs industrialize and develop.[30] As one example, computer scientist Abdou Maman Kané founded Tech Innov in Niger in 2018.[31] This company's mobile apps enable farmers to regulate irrigation systems remotely and more effectively and efficiently while simultaneously collecting relevant meteorological and hydrological data. Since its launch, Tech Innov has attracted investment from several arenas, including the private funder Synergi and a USAID/Investisseurs & Partenaires joint program that funds promising tech companies in Burkina Faso, Niger, and Senegal.[32]

Building stronger relationships with international partners is essential if the United States is to play an effective leadership role in facing climate change, a major threat to national and global security.[33] LMICs, including ESPs, play a critical role in climate change as they are on the forefront of experiencing climate impacts and exploring ways to address them (see Climate Adaptation in the Pacific on page 7). Collaborations between U.S. researchers and ESPs can enhance the latter's ability to do this while also enabling both partners to exchange not only innovations and processes, but also strategies related to the human and social dimensions of adaptation and mitigation to climate change.

Preparing for and Responding to Pandemics: Emerging Infectious Diseases

Emerging infectious diseases (EIDs) are communicable diseases that are newly introduced in a population or are known but are showing increasing incidence or geographic range.[34] Along with climate change, the increasing

Climate Adaptation in the Pacific Islands and the Pacific Rim

Pacific Island nations are among the most vulnerable to the impacts of a changing climate.[35] Some small islands in the Solomon Islands archipelago have been fully submerged; on others, full villages have been lost.[36] Rising sea levels and environmental degradation resulting from overpopulation, pollution, and unsustainable development demand swift and strategic action.[37] As a result, many Pacific Island nations have become hubs of climate innovation and are paving the way for implementing smart development plans.[38]

Palau established a national climate adaptation plan in 2015 that would enhance adaptation and resilience to changing global factors, improve the ability to respond to and minimize disaster risks, and promote sustainable development practices.[39] The framework outlines strategic investments to support R&D endeavors that will promote the nation's development and climate-resiliency goals. One of these projects, funded by USAID, seeks to merge traditional farming techniques with modern practices to increase food security and coastal ecosystem resiliency, thereby mitigating disaster risk.[40]

The United States already faces—and will continue to face—many similar challenges to those that the islands in the Pacific now face, including sea-level rise, increased storm and disaster risk, and threats to ecosystem integrity. Climate adaptation strategies that have already been successfully implemented elsewhere could be useful for the United States to study and adapt to meet the challenges and risks of environmental change here.

Beniamina Island, in the Solomon Islands Archipelago, in 2016. Source: Simon Albert, "Uneasy Waters," University of Queensland, Australia.

Many countries have begun to design and implement plans that seek community input and buy-in and merge strategies from both traditional Indigenous knowledge, especially from women, and proven sustainable modern practices.[41] Initiatives and programs that are designed and led by local communities and account for traditional knowledge and cultural norms often have better results.[42]

Some scientists working to address environmental concerns have taken this approach in working with Indigenous and First Nations communities in Alaska and British Columbia, respectively. In efforts to recover sea otter populations to restore ecosystem integrity on the Alaska-Canada coastline, scientists quickly realized that, without working collaboratively with local Indigenous and First Nations communities, restoration efforts could fail because an increase in sea otter populations could threaten the abundance of shellfish, a dietary staple for many of the communities.[43] In codeveloping adaptation and land management strategies with traditional environmental management practices, restoration efforts and ecosystem management are progressing in a more mutually beneficial manner.[44]

demand for livestock and animal husbandry and encroachment into wildlife habitat by human beings raise the potential for more "spillover events" where animal pathogens cross over into the human population.[45] Such events are often responsible for driving the spread of EIDs and occur when viruses leap from wildlife to human beings.[46] These diseases can spread in various ways through air, food, or water or through vectors such as mosquitos and ticks; 60–80 percent of new diseases in human beings originate in animals.[47]

Surveillance of EIDs will be vital to the world's ability to respond quickly and efficiently to dangerous pathogens. These efforts require global collaboration, as pathogens can move quickly around the globe. ESPs are key partners in this work, as many identified hot spots of possible spillover events are in the Global South.[48] Developing the broad capabilities to identify, characterize, treat, and prevent the spread of resulting infections in all locations of possible spillover will allow the world to respond more quickly to outbreaks and pandemics in the future.

For example, while many ESPs may not have had the same level of access to the scientific technologies available in wealthier nations, several were initially comparatively successful at containing the spread of COVID-19 when it first emerged, likely due in part to prior experience mitigating the spread of infectious diseases.[49] Following outbreaks of other EIDs, including the deadly severe acute respiratory syndrome (SARS) epidemic in 2003 and the H1N1 epidemic in 2009, countries in East and Southeast Asia increasingly invested in research to prepare for the possible emergence of zoonotic coronaviruses and influenzas.[50] In Africa, scientists have drawn attention for their research and management of outbreaks of the highly contagious Ebola virus in West Africa from 2014 to 2016 and in the Democratic Republic of the Congo from 2018 to 2020.[51] Building a strong, science-driven and -informed public health infrastructure to respond to pandemics in all countries of the world is important for containing and mitigating the spread of contagious pathogens like SARS-CoV-2.

As the world seeks to bring about the end of the COVID-19 pandemic, nations must remain vigilant. By collaborating internationally and supporting capacity-building initiatives, the United States and its global partners will be better positioned to respond to the next pandemic threat. The United States must support and fund such endeavors as an important investment for both national security and global health (see Stopping COVID-19 and Preventing the Next Pandemic on page 9).

Enabling Scientific Breakthroughs

Many scientific endeavors require global collaboration, especially when projects are too expensive for one nation to fund alone, when global data collection is paramount for scientific goals, and when the key scientific talent is internationally based.

One example of the key role ESPs can play in such efforts is the Square Kilometer Array (SKA), an international collaboration whose goal is to build the world's largest radio telescope. When completed, the array will have the capacity to survey the entire southern sky and the ability to detect millions of radio sources faster than ever before, allowing enhanced detection of transient events.[52]

The telescope array will be located in South Africa and Australia, with nearly two hundred mid-frequency dishes located in the Karoo

Stopping COVID-19 and Preventing the Next Pandemic

The world first learned the viral sequence of SARS-CoV-2, the virus that causes COVID-19, on January 12, 2020, upon the open publication of the viral genome by scientists in China.[53] Although the disclosure of scientific information may have been delayed for weeks by political leaders, the viral sequence and other research findings from Chinese scientists were key resources for international scientists, governments, and public health organizations, including for scientists at the NIH who would go on to develop an efficacious vaccine in collaboration with Moderna.[54]

Simultaneously, researchers in Thailand, working closely with CDC researchers based outside Bangkok, used information from Chinese researchers to design a PCR test for the novel coronavirus and were able to confirm the first case outside China.[55] They accomplished this feat before the World Health Organization (WHO) released its test, and John R. MacArthur, who leads the CDC's Thailand operations, contacted his agency's leadership in Atlanta to share the Thai-developed resource.[56] In what would prove to be an unfortunate decision, the CDC did not use either the Thai-developed PCR test or the WHO-approved test, choosing instead to develop its own test. The CDC-developed test received emergency authorization on February 4, but rollout was delayed when investigators discovered issues with the reagents. This left the United States without a rapid, accurate test in the early days of the pandemic, a period when detection and containment were essential components of preventing widespread infection. Ultimately, the United States was unable to develop its own test until forty-seven days after the Thai researchers had shared their protocol directly with MacArthur and his CDC colleagues in Bangkok.[57]

Researchers with the American and Asian Centers for Arboviral Research and Enhanced Surveillance traveling by canoe in a river in Esmeraldas, Ecuador, to rural remote communities that are part of A2CARES field sites. Photo courtesy of Maurico Ayovi and A2CARES Research Center.

These two moments highlight the fact that international connectedness, including with ESPs, provides major opportunities for U.S. scientists to move quickly and effectively to address threats. Researchers, including those with the WHO's Global Preparedness Monitoring Board, have concluded that the lack of a strong, coordinated, global response resulted in difficulty containing and mitigating the impact of SARS-CoV-2, causing an immense, devastating loss of life.[58]

To meet the need for improved international connections, the NIH's National Institute of Allergy and Infectious Diseases (NIAID) established the Centers for Research in Emerging Infectious Diseases (CREID) network in August 2020. It is coordinated by RTI

continued on next page

region of South Africa (and likely extending farther north into the continent) as well as approximately 130,000 low-frequency antennas across Western Australia.[59] With the vast surveying capabilities the SKA will provide, astronomers hope to gain insight into some of the biggest questions about the universe, including how galaxies evolve, the origins and evolution of cosmic magnetism, and, by searching for extraterrestrial signals in space, whether intelligent life exists elsewhere in the universe.[60]

In South Africa, the SKA project will integrate instruments constructed for the MeerKAT radio telescope, which launched as a precursor to the SKA in 2018.[61] MeerKAT has attracted scientific talent from around the world and has helped to make South Africa a leader in astronomical sciences. In 2019, scientists using MeerKAT discovered a unique flare of radio emission from a binary star—just the first of many transient events scientists hope to discover using MeerKAT and, eventually, the SKA.[62]

Global S&T Capacity and the Global S&T Workforce

To maximize the benefits from U.S.-ESP collaborations over the long term, capacity building is a key challenge to address.

The next generation of scientific talent and leadership may be increasingly likely to be concentrated in ESPs: as of 2019, nineteen of the twenty countries with the youngest inhabitants are in Africa, where the population

Stopping COVID-19 and Preventing the Next Pandemic, *continued*

International and Duke University's Human Vaccine Institute.[63] Over the next five years, NIAID intends to provide $82 million to support the network's research.

Research centers hosted at U.S.-based institutions, as well as one in the United Kingdom, will collaborate with affiliated research sites in twenty-nine countries, primarily in the Global South, each focused on studying existing pathogens and surveilling potential new pathogens in one or more regions of the world.[64] In addition, the CREID network launched a pilot research program in 2021 to mentor and train the next generation of emerging infectious disease researchers and in-country scientists to enhance emerging disease research capacity.[65] The 2021 awards supported research on transmission dynamics, surveillance, and immunity for a variety of viruses, including SARS-CoV-2, Yellow Fever, Hantavirus, and Arboviruses, among others. Awardees included scientists from Jordan, Brazil, Vietnam, Kenya, and Cambodia.

After the COVID-19 pandemic has passed, the world will remain vulnerable to future threats. New infectious diseases will emerge. Full pandemic preparedness depends on all countries of the world. The cost of investing in pandemic prevention pales in comparison to the cost of pandemics to the world economy; for example, the cost of the COVID-19 pandemic to the United States alone is estimated to be as high as $16 trillion, whereas the cost for global pandemic prevention and preparedness is measured in the billions.[66]

Viruses are not deterred by national borders. Finding solutions to mitigate their spread and impact will require cooperation at bilateral, regional, and international levels.[67]

Paul Kagame, President of Rwanda, addresses the audience at the Next Einstein Forum, March 26, 2018. Photo © by Paul Kagame.

is projected to increase by 237 million from 2019 to 2050. At the same time, nearly all countries with established scientific enterprises and significant R&D investments are home to aging populations.[68] Collaborations between the United States and ESPs would build strong ties and relationships, allowing for further exchanges of ideas, samples, and data to prompt transformative innovation and discovery for years to come. A focus on the potential of Africa's young population led to the development of the Next Einstein Forum, an initiative of the African Institute for Mathematical Sciences and Robert Bosch Stiftung, which was founded on the belief that the next Einstein will be from Africa.[69] The program supports research fellowships that develop technology and innovation to build a robust network and increase the capacity of Africa's tech workforce.[70] Greater participation of these youth in U.S. graduate education programs could also increase that capacity.

Increasing Scientific Capacity in ESPs

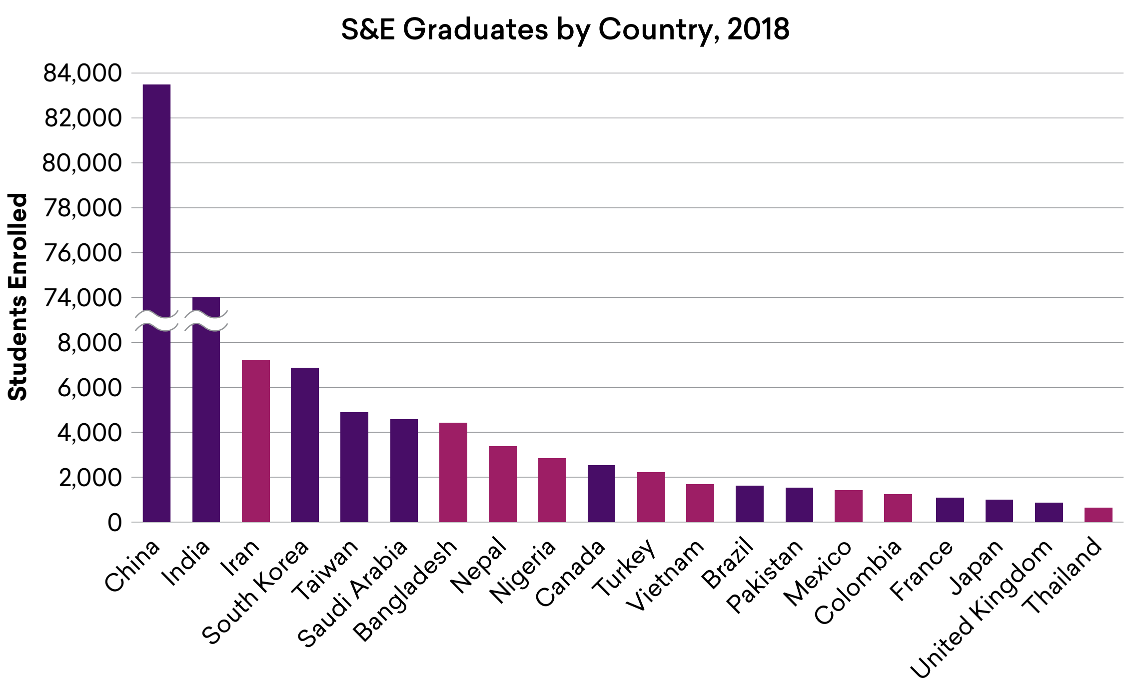
Much of the world's scientific productivity is concentrated in countries with historic and robust investments in science, technology, and innovation, including the United States, United Kingdom, France, Germany, China, Russia, Japan, and South Korea.[71] Many LMICs are following their lead and working to expand and strengthen their own scientific enterprises.[72] These national investments in science are pathways to improved development, including enhanced economic growth, improved health, and the reduction of poverty and food insecurity.[73] Many global organizations also work toward these goals, including the Global Research Council and the United Nations, especially the UN Educational, Scientific and Cultural Organization (UNESCO). The UN's SDGs provide a framework for many LMIC development and strategic investments. However, since the United States withdrew from UNESCO in 2017, other nations, primarily

China, have stepped in to wield greater influence over UNESCO's goals.[74]

Today's ESPs hold the potential to break into the global scientific ecosystem with top scientific publications and talent. As more countries become globally competitive and the share of top-cited publications is distributed across countries and regions, top-tier science will be performed around the world and will push innovators to new frontiers. Sustained investment from the United States and others in long-term capacity building will help to accelerate progress toward this goal. In particular, encouraging the participation of women and marginalized groups in STEM, both in ESPs and in the United States, is a major opportunity for expanding science capacity in the United States and internationally (see Women in Science & Technology on page 13).

While applied research can address specific problems and lead to significant economic development in ESPs, investment in fundamental science should also be expanded. ESPs are often encouraged to pursue applied R&D solutions in the short term, leaving less funding available for fundamental research.[75] Understanding the foundations of physical, life, and chemical sciences can lead to productive innovation and technology and is needed to inform productive applied science studies.[76]

International Science and Engineering (S&E) **Graduate Students** in the United States



Note: The figure shows the twenty countries with the greatest number of students pursuing S&E graduate degrees (master's and Ph.D.s) in the United States. ESPs are shown in magenta.
Source: National Science Board, *Science and Engineering Indicators 2020,* Table S2-14.

Women in Science & Technology:
A Necessity for the Global STEM Workforce

Increasing women's participation and leadership in S&T careers is a key opportunity for raising S&T capacity worldwide: women represent approximately half of the global population but less than 30 percent of researchers.[77]

Women's participation in S&T varies by country and region, but 103 out of 143 countries report women researcher levels below parity, including both high-income countries and LMICs alike. Regional averages are all below 50 percent, although Central Asia and Latin America and the Caribbean lead the world and are approaching parity at 48.5 percent and 45.8 percent women researcher participation, respectively. South and West Asia, East Asia and the Pacific, and sub-Saharan Africa have some of the lowest rates of women researcher participation at 23.1 percent, 25.0 percent, and 31.1 percent, respectively.[78]

In the United States, implicit and explicit biases alongside structural and interpersonal impediments continue to obstruct women's ability to participate fully in scientific research across disciplines.[79] These barriers can be even more severe for women researchers of color, as the impacts of racism and sexism intersect.[80] Leading scientific institutions and national policy-makers have identified this underrepresentation as a major threat to U.S. global competitiveness in R&D and are working to expand the STEM workforce accordingly.[81]

Global networks of scientists are also working to address gender disparities. As one example, the international initiative GenderInSITE is actively working to promote the inclusion of women in STEM fields and to demonstrate the important benefits that gender parity can bring to science and to development in general.[82] In coordination with the InterAcademy Partnership and International Science Council, GenderInSITE collects and analyzes relevant data, conducts global surveys of science academies, and tracks progress on gender equality made by these influential bodies. Their most recent report finds that women's representation in global scientific academies is increasing on average but still far from parity, noting an increase from 13 percent in 2015 to 17 percent in 2020. Currently, academies of young scientists report the largest shares of women's membership. Overall, female representation is significantly lagging in some scientific disciplines compared to others; for example, women on average comprise only 8 percent of members in mathematical science disciplines.[83]

These statistics have important implications for policy-making; science academies play a major role in informing decisions related to development. Without an application of a gender lens to these decisions, women and girls will be less likely to benefit from such interventions and may suffer adverse consequences.[84]

To build an effective and robust global S&T workforce, the United States must increase participation of women, both in the United States and in its collaborations internationally. In consultations with women scientists in ESPs around the globe, the CISP initiative repeatedly heard that women face specific barriers in science. The mechanisms endorsed by this report include considerations of these barriers and, if implemented, would work toward overcoming them.

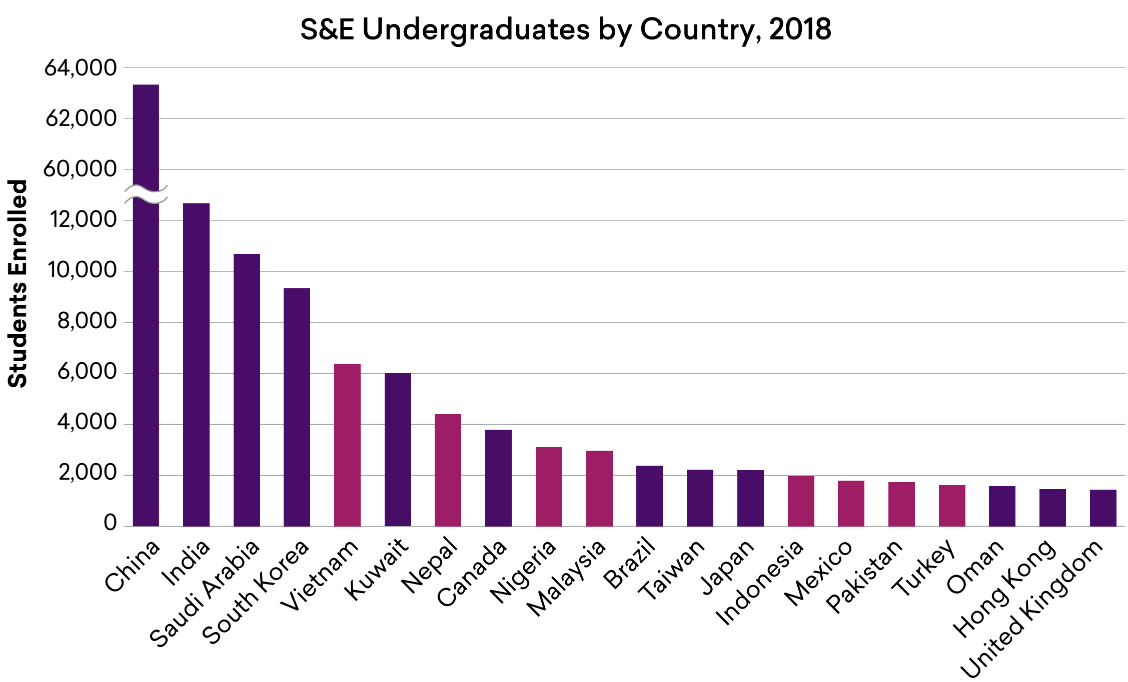
Increasing Scientific Capacity in the United States

Ultimately, increasing scientific capacity in ESPs will significantly benefit U.S. scientists and the United States more broadly. The United States needs to continue to foster these relationships, working to develop emerging scientific enterprises so that the next generation of innovation can benefit all.

U.S.-based scientists collaborate with international colleagues, including with researchers in ESPs, in the pursuit of the highest-quality science.[85] Countries that have significantly expanded their scientific enterprises in recent decades, such as India and South Korea, saw corresponding growth in collaborations with the United States.[86] As they build their scientific enterprises, ESP scientists are likely to follow these patterns.

The United States has also long benefited from the international researchers who have been attracted to U.S. universities and scientific institutions, especially at the undergraduate, graduate, postdoctoral, and early career research stages. Some of these scientists remain in the United States after completing their training; others return to their home countries and advance international institutions. Both paths provide significant benefits to the U.S. R&D enterprise, as U.S. scientific centers are well-connected to the world's top talent, both domestic and international. ESP researchers are a key component

International Science and Engineering (S&E) **Undergraduates** in the United States



Note: The figure shows the twenty countries with the greatest number of students pursuing undergraduate degrees in all S&E disciplines in the United States. ESPs are shown in magenta.
Source: National Science Board, *Science and Engineering Indicators 2020,* Table S2-13.

of this "brain circulation," and their participation in the U.S. scientific enterprise should be encouraged (See Figure: International Science and Engineering Graduate Students in the United States). Indeed, researchers from ESPs have earned substantial fractions of U.S. STEM degrees granted to international students: nearly half of bachelor's degrees, nearly one-third of master's degrees, and approximately one-quarter of doctorates.[87]

In addition to welcoming ESP talent, support for connections between U.S. and ESP researchers is an important component of building a robust U.S. R&D enterprise that pursues the best science, no matter where a collaborator or experiment is based. The H3Africa collaboration, as one example, substantially adds to the capacity of U.S. researchers' ability to uncover the genetic bases of disease. Without African collaborators, including those based in ESPs, the genetic diversity in sequenced datasets would be less complete for U.S. biologists' analyses.[88] H3Africa has worked closely with its collaborators to define clearly ethical principles for this research and to clarify ownership of samples, data, and other intellectual property (IP). Long-term, sustained investment in ESP institutions can provide the United States with an expanded pool of global research collaborators that indirectly boosts the U.S. S&T enterprise.

South Korea is a prominent example of such success. At the end of the Korean War, South Korea was one of the poorest nations in the world.[89] With seed funding from the U.S. government to aid in establishing institutions such as the Korea Institute of Science and Technology (KIST, founded in 1966) and KAIST (initially the Korean Advanced Institute for Science, KAIS, founded in 1971), as well as a long-term domestic commitment to invest in R&D, the country began a remarkable trajectory. Today it is one of the most innovative nations in the world, home to immensely successful technology companies such as Samsung, Hyundai, and Kia.[90] South Korea is now sought out as a collaborator by international partners, including the United States, and is a magnet for attracting global talent to conduct research at its scientific institutions.[91]

Today, KIST is committed to promoting prosperity abroad by providing international aid and grant funding for R&D to ESPs around the world, with the aim of inspiring similar transformations in other nations.[92] In 2013, the presidents of Vietnam and South Korea made a joint declaration to establish the Vietnam-Korea Institute of Science and Technology (V-KIST) as a public science agency under the Vietnamese Ministry for Science and Technology.[93]

Large-Scale Facilities for Capacity Building

As discussed in CISP's report *Bold Ambition: International Large-Scale Science*, large-scale science facilities enable scientists to answer questions that range from the minuscule to the gargantuan—from the structures of subatomic particles, atoms, and complex biomolecules to the origin of the universe. These facilities also create opportunities for increased collaboration among scientists.[94] In ESPs, construction of such facilities is important for building scientific capacity and for creating opportunities for increased collaboration with international scientists. Synchrotron light sources and the SKA are two such examples of the capacity-building potential of large-scale facilities for ESPs.

Synchrotron Light Sources

Synchrotron light sources are major facilities that address many physical anthropology, biology, chemistry, engineering, medicine, and physics research questions.[95] The need for such a resource in the Middle East drove the construction of the Synchrotron-light for Experimental Science and Applications in the Middle East (SESAME). In seeking to build SESAME, Jordan hoped not only to build an advanced facility to promote scientific progress in the region but also to provide a platform for strengthening peaceful diplomatic relations in a fraught political landscape.[96]

Efforts to bring light sources to other regions of the world are underway with similar goals. Lightsources.org is a collaboration seeking to enhance the connections between the more than fifty finished or under construction light sources distributed across the globe.[97] The International Science Council, the International Union of Pure and Applied Physics, and the International Union of Crystallography have partnered to form Lightsources for Africa, the Americas, Asia, Middle East, and the Pacific (LAAAMP), a project that seeks to enhance access to light source facilities in regions interested in boosting scientific capacity.[98]

LAAAMP supports the African Light Source Foundation in its effort to establish the first African light source. Recognizing the potential scientific and economic benefits such a facility could provide, African scientists and policymakers are working to develop a road map to obtain the government support necessary to construct a light source.[99] At the second African Lightsource Conference, held in 2019, Ghana emerged as the primary champion of the project and is working to establish the light source as a formal project of the African Union and the Economic Community of West African States.[100]

The almost fully assembled SKA-MPI prototype dish of the SKA project on the South African site. Photo © by SARAO/Angus Flowers.

Efforts to increase international access to facilities could be a key pathway to advancing and expanding scientific capacity in ESPs. For example, the only light source facility in Latin America and the Caribbean, the Laboratório Nacional de Luz Síncrotron in Campinas, Brazil, has partnered with the American Physical Society to foster connections between young scientists in the United States and Brazil and advance physical research in both nations.[101] Efforts to expand user access within the region, including to scientists from ESPs in the Caribbean, could prompt the development of a regional scientific enterprise as well.[102]

In Southeast Asia, LAAAMP's strategic plan includes making the Synchrotron Light Research Institute located in Thailand the main light source facility in the region. LAAAMP also works to encourage other Southeast Asian countries to invest in training programs that would grow a scientific workforce versed in the operation and scientific applications of light sources.[103]

The Square Kilometer Array

The SKA also provides significant infrastructure and capacity-building opportunities for African science. The project will produce enormous volumes of data and requires new technology to run it, including the world's fastest supercomputer.[104] The infrastructure needed to store, manage, and analyze this data will require significant capacity development in science, engineering, and technological innovation, opening opportunities for collaboration across scientific disciplines and between the public and private sectors, creating huge opportunities for African tech.

To meet the scientific demands of the instrument, the SKA established the Human Capital Development Programme to provide funding for master's and Ph.D. students in radio astronomy.[105] From the program's launch in 2005 through 2018, it has provided 455 million rand (approximately $30 million) in grant funding to 1,054 students, including 802 students from South Africa, 176 from other African countries, and 76 students from non-African countries.[106] Additionally, the program will invest in developing a skilled maintenance workforce and create significant construction jobs and opportunities for the community.[107] Still, many in the local community opposed the construction of the telescope, with many of the poorest residents concerned that they would not be able to partake in the benefits of these investments.[108] The leadership of the project initially promised significant returns to the farmers, largely people of color, who provided their land. The SKA has struggled to meet expectations, however.[109] To address farmers' concerns, the SKA partnered with the community organization Agri SA to negotiate the purchase of land from landowners and ensure that the community will benefit from the project.[110]

Construction for the SKA was originally intended to begin in 2020. Because of the COVID-19 pandemic, construction was postponed. In addition, SKA had not collected sufficient funding to begin.[111] In June 2021, seven countries, including China, the Netherlands, Italy, Australia, the United Kingdom, and Portugal, ratified the Convention Establishing the SKA Observatory, providing the necessary boost in funding support needed to approve the start of its construction that same year.[112] The United States participates through the National Radio Astronomy Observatory (NRAO), a National Science Foundation (NSF) facility that operates telescopes in the United States and South America. The SKA and the NRAO signed an MOU in 2017 to collaborate on development of common software for data reduction in radio astronomy that is scalable to the future needs of the SKA.[113]

Global Understanding, Science, and Diplomacy

Global scientific collaboration has the potential to contribute meaningfully to the broader goal of promoting international understanding across cultures. Engagement with ESPs, and the Global South in general, which represents a substantial portion of the world's population, is a key component of this strategy that will only grow in importance as ESPs expand their S&T enterprises.

Diplomacy for Science

Diplomatic engagement is a key mechanism for building international scientific collaborations in established scientific relationships and ESPs alike, both for initiatives that become flagship projects and for partnerships at the grassroots level (see Science Envoys on page 19).[114] In large-scale ventures, the United States must take care to meet commitments for scientific cooperation made in these diplomatic exchanges. In the past, joint initiatives have often led partner countries to hold expectations that went unmet.[115]

Global bodies and their regional branches, such as the InterAcademy Partnership (IAP), International Science Council (ISC), and International Network for Government Science Advice (INGSA), are important entry points for interacting with scientists who have international and diplomatic experience. Building relationships with regional ESP branches and leadership at these levels can strengthen efforts in science diplomacy and present key opportunities for sharing knowledge between U.S. and ESP leaders.

Science for Diplomacy

Scientific collaborations can also contribute to positive relations with other countries, including potential or actual adversaries. By building a foundation for discussion based on shared goals, collaboration can potentially prevent military interventions and conflict, as some scholars argue was the case with the United States and the Soviet Union during the Cold War.[116] In addition, shared scientific interests provide an additional channel for diplomatic relations, as science diplomacy can create trusted relationships. In the best cases, science is a common language based on shared values and goals that can connect countries otherwise at a great distance from each other.[117]

The United States is not alone in leveraging scientific collaboration to advance diplomatic goals. China's BRI, a major infrastructure construction program launched in 2013, has signed memoranda of understanding (MOUs) with more than one hundred countries, many of which are ESPs (see Figure: One Belt, One Road on page 20).[118]

The BRI has significantly expanded China's sphere of influence in the world, not only by growing its trading markets but also through infrastructure investments that promote enhanced partnerships and collaborations. The total cost of projects thus far completed, in progress, or planned amounts to more than $1 trillion, although estimates of the true cost vary immensely.[119] Scientific partnerships have been a core component of China's BRI involvement in Africa, which has included the construction of scientific laboratories and research centers and the creation of grant opportunities and scholarships for African students. As of 2014, China had surpassed the United States and the United Kingdom in the number of African students educated at its

Science Envoys: Building International Connections Abroad

In 2009, Senator Richard Lugar (R-Indiana), then the ranking minority member of the Foreign Relations Committee, proposed the creation of a U.S. Science Envoy Program as a means of science diplomacy outreach to foster international scientific collaboration.[120] To date, twenty-two esteemed scientists and engineers have served as U.S. science envoys.

Science envoys serve one-year terms and work to build international scientific networks and promote American scientific values, including public support for merit-based scientific institutions and respect for science in society.[121] They contribute to science diplomacy and work at multiple levels of scientific ecosystems, building peer-to-peer connections between researchers and advising U.S. government representatives on opportunities for scientific collaboration abroad.

This type of international outreach and engagement is valuable for the United States and for ESPs where scientific capacities are increasing and may particularly benefit from the ideas, networks, and models for effective government support of science that U.S. science envoys can bring. The U.S. Science Envoy Program also can help elevate and expand the visibility of a country's national discussion about the role of S&T. Looking to the future, especially in an increasingly virtual scientific world, the program could be profitably expanded to include a more diverse assembly of scientists and engineers and could also align its goals and activities with programs that involve early career scientists. Because it can take a year for an envoy to get well-engaged, two-year terms should be considered.

Although the envoys are unpaid, their effectiveness depends on strong connections with in-country embassies. Effectiveness is further enhanced when envoys are allocated modest resources to fund workshops and other activities. Such engagement must be supported by the U.S. government more broadly, must be supported with funds that allow envoys to bring other U.S. scientists to engage with ESPs, and must be sustained over time.[122] By doing so, the United States can foster mutually beneficial collaborations with ESP scientists and governments, while helping to build respect for and friendships with the United States.

Former astronaut and National Aeronautics and Space Administration (NASA) administrator Major General Charles Bolden visited South Africa as the Department of State's U.S. science envoy for space. During his week-long trip, Bolden engaged with high schoolers, university students and faculty, aerospace professionals, and the general public. Photo courtesy of U.S. Embassy South Africa, November 15, 2018.

universities.[123] Although China's BRI has been relatively well received by countries that have signed MOUs, many in the United States are concerned that the initiative's commitment to spreading digital access may be a method to increase Chinese surveillance and authoritarianism in participating countries.[124]

International scientific relations can be improved by engagement at all levels, ranging from peer-to-peer collaborations that build trust between individual researchers to investments in large-scale facilities that provide infrastructure that can drive innovation and advancement regionally (see Collaboration in Conflict Zones: Resource Conservation in Afghanistan on page 21). The United States must continue to recognize, value, and expand its engagement with ESPs, as other countries, both U.S. allies and competitors, continue to strengthen their own networks of relationships with ESPs.

One Belt, One Road

A visualization of China's Belt & Road Initiative, which seeks to develop infrastructure connections between Asia, Europe, and Africa. More recently, the initiative has expanded significantly into many countries in Africa and includes infrastructure projects in South and Central America. **Source:** iStock.com/Silk Road.

Collaboration in Conflict Zones: Resource Conservation in Afghanistan

Afghanistan is home to an abundance of biodiversity, with thriving populations of animals as varied as flamingos and snow leopards and containing within its borders a wide range of ecological biomes, including immense canyons, deserts, meadows, forests, and the western range of the Himalayan Mountains.

Decades of violent conflict beginning in the 1970s and carrying through to today have left Afghanistan a war-torn nation, leading to significant conflict within its human populations and indirectly impacting the country's biodiversity and natural resources.[125] Wildlife conservation seems an unusual priority in a war-torn, politically unstable context; however, with 74 percent of the country's population residing in rural areas and 80 percent of the population dependent on agriculture, the conservation of natural resources must be made a priority.[126] Severe droughts impact the majority of provinces in the country, and the nation's primary source of water, glacial melt in the Hindu Kush mountain range, is disappearing.[127] Preventing conflict driven by food and water insecurity demands conservation and preservation of natural resources. Thus it is essential to develop natural resources conservation policies and practices.

In 2006, the Wildlife Conservation Society, headquartered at the Bronx Zoo in New York, launched a new Afghanistan program with funding from USAID. The aim of the program was to conduct the first baseline assessment in thirty years of the country's biodiversity and natural resources, develop community-driven conservation priorities and policies, and build the technical and scientific capacity necessary for Afghans to continue the work through locally driven initiatives at all levels of governance.[128] Following the successful outcome of this first project, USAID funded a subsequent project from 2010 to 2014 that sought to understand how conservation of natural resources could directly improve livelihoods and resource governance in the country.[129]

Several partners based in Afghanistan and in the United States collaborated on the extensive biodiversity and demographic survey. The work engaged more than fifty-five rural communities in Afghanistan and helped to link them to the central government agencies, trained more than ten thousand Afghans at local and national levels in sustainable resource management, and led to the strategic protection of over 1.2 million hectares of watersheds.[130] Additionally, the information gathered was used by the government of Afghanistan to establish a network of national protected areas and to help determine what infrastructure would be needed to successfully operate and maintain these areas. As a result, the country's first national park, Band-e-Amir, was established in 2009.[131] It is hoped that this park will continue to be a positive example and force in Afghanistan as that country faces more turmoil and another change in government.

U.S. Leadership

For the United States to maintain its position as a global leader in science, including as a top collaborator with ESPs, it must continue to support and invest in international partnerships. ESPs represent an enormous opportunity for collaboration and partnership. As pointed out in the earlier CISP reports, if the United States removes itself from the influential position it has held in the science ecosystem, other nations, such as the United Kingdom, countries of the European Union, South Korea, Japan, and China, could fill this vacuum.

This trend is already apparent when observing the United States' status as a global leader in R&D expenditures. In 2000, the United States had the largest share of worldwide R&D expenditures at 37.1 percent. In comparison, the European Union, China, and other East-Southeast and South Asian countries had shares of 21.8 percent, 4.5 percent, and 20.7 percent, respectively. By 2019, the United States held just 27.3 percent of the share of global R&D, while the European Union held 18.2 percent, China held 21.9 percent, and other East-Southeast and South Asian countries held 17.9 percent.[132] From 2000 to 2019, the United States contributed 23 percent of the worldwide growth in international R&D spending. Meanwhile, East, Southeast, and South Asian countries contributed 46 percent (China: 29 percent; South Korea and Japan: 9 percent; other East-Southeast and South Asian countries: 7 percent).[133]

Notable trends also emerge when looking at R&D intensity (i.e., R&D as a percentage of GDP) over time. From 2000 to 2019, the United States increased its R&D intensity from 2.63 percent to 3.07 percent. Over the same time frame, China increased from 0.89 percent to 2.23 percent, South Korea increased from 2.13 percent to 4.64 percent, and Germany increased from 2.41 percent to 3.18 percent.[134] This trend underscores the reality that S&T is a growing national priority for many countries, especially those in the East. Meanwhile, U.S. federal R&D expenditures have been declining across all research types and sectors between 2010 and 2019.[135] Should countries like China and South Korea continue to increase their R&D intensities, they will likely continue to have increasing shares of global R&D expenditures moving forward.

Diminishing our leadership role could have enormous influence in shaping future science innovation and technology.[136] The engagement that develops through research partnerships also has a significant impact on questions of national and economic security. These observations hold true for partnerships with the ESPs as well as partnerships with nations with established S&T enterprises.

As the United States navigates this increasingly complex landscape of global research, it must balance the need for cooperation and competition. Nations of the world are interdependent. We must cooperate as we face shared global challenges. At the same time, the United States must be fully engaged as a nation to maintain our leadership role in the face of the growing global competition for partners, talent, and markets. Through international science collaboration, balancing these two needs is both a possibility and can lead to a more interconnected and more prepared global research community.

Science for **Global Development**

High-wealth countries, including the United States, often provide funding to ESPs in the form of development assistance. There are opportunities to expand the leadership position of the United States as science and innovation increasingly drive development as outlined in the discussion with donors below.

Science and innovation have played critical roles in bolstering economic development. Advancements in agricultural sciences, such as plant breeding and bioengineering resilient crops, have been and will continue to be instrumental in preventing famine and providing food security. Discoveries in medicine and global health have improved the economic status and quality of life for millions of people. Technological innovations, initially created for scientific research purposes, have had enormous impacts on today's world.

The United Nations, through its seventeen sustainable development goals (SDGs), is the leading global organization coordinating international efforts to promote and guide science-driven sustainable development.[137] The SDGs are used by many countries to identify basic and applied science needs that will help to meet a series of sustainable development benchmarks by 2030.[138] For example, the African Union's Science, Technology and Innovation Strategy for Africa 2024 outlines strategic investments that African governments can make to reach science development goals by 2024, including by liaising with various branches of the United Nations.[139]

In addition to cooperating with UN initiatives, many wealthy countries support individual science capacity-building programs through their own development agencies. Programs such as those developed by the United States, the United Kingdom, Sweden, Germany, other countries of the European Union, Canada, South Korea, Japan, and Australia acknowledge the role of S&T in fostering development and work with partner governments or funding agencies in ESPs to provide specific project funding for scientific research and capacity building. China is also a major funder of capacity building through various agencies and initiatives, including through its BRI, which includes expansion of scientific infrastructure and training programs, with a significant focus on Africa.[140]

Many wealthy countries, the United States included, support global development as an important goal through official development assistance (ODA).[141] As of 2020, ODA from member countries of the Organisation for Economic Co-operation and Development (OECD) Development Assistance Committee was equal to $161.2 billion, an increase of 3.5 percent from 2019, with the United States making the greatest contribution at $35.5 billion.[142]

In January 2020, the CISP project held a roundtable discussion with representatives from several bilateral and international funding agencies whose programs support science-related development initiatives in ESPs. Despite sharing similar priorities, the approach and execution of such programs vary significantly across funding agencies and countries. Over two days of discussion, two major concerns arose: building sustainable and resilient programs and incorporating ethical codes of research.

Building Sustainable and Resilient Programs for the Local Context

During the roundtable, strengthening research capacity was defined as: enhancing the ability and resources of individuals, institutions, and systems to undertake, communicate, and use high-quality research efficiently, effectively, and sustainably. Many governmental ODA science-funding programs, including USAID's PEER Program, the UK Research and Innovation Newton Fund and Global Challenges Research Fund, and Japan's Science and Technology Research Partnership for Sustainable Development, have the goal of increasing scientific capacity in their ESP partners, with the programs serving as a foundation for launching a sustainable research enterprise.[143]

For programs to be successful in the long term and to continue past the initial collaboration, funders should work with ESP partners to build capacity and embed research and scientific programming in the local infrastructure. For example, programs need to have realistic designs and genuinely engage with ESP institutions and not rely solely on institutions or structures in place in funder nations. For expertise that is not available locally, such as administrative capacity or specialized legal knowledge, funders should seek to build local capacity. The scope of programs will vary greatly, but efforts need to be made to look more broadly at the overall ecosystem of scientific research, which includes not only the focal individual researchers and organizations but those less central to the research itself; for example, those who communicate about or use the resulting science.

The Ethics of Collaborative Programs in ESP Contexts

Considerations regarding ethics and transparency must be central to U.S. research partnerships with ESPs and cannot be viewed simplistically. Ethics must encompass what is being researched and why, the generation of knowledge in and of itself, and how research is being conducted in an evolving context. What are the risks? Who benefits, and how?

Ethics must be an ever-evolving conversation because societal dynamics shift and technologies and innovations advance.[144] Addressing ethical considerations and concerns directly and transparently is important. Cultural differences and communication challenges can play a role in misunderstanding, and efforts need to be made to avoid such problems. Funding agencies, research institutions, and researchers partnering with ESPs should codevelop principles and guidelines for conduct that honor the fundamental values of ethical research: honesty, fairness, objectivity, reliability, skepticism, accountability, accessibility, and openness.

Conversations about the conduct of research, the behaviors of researchers, and the allocation of credit should begin at the outset of any collaboration and then continue. Open conversation can establish a strong foundation of trust and understanding between partners and set the stage for promising long-term programs.[145]

U.S. Collaborators for ESP Engagement

Many ESP governments have not yet fully incorporated R&D funding as a strategy for economic growth and prosperity. In Africa, many governments have stated their commitments to investing at least 1 percent of their GDP into R&D.[146] However, available data indicate that none have met this goal, and investment remains especially low in sub-Saharan Africa. As of 2017, South Africa had the highest investment on the continent with 0.83 percent of its GDP supporting R&D.[147]

Given this reality and the recognition that ESPs must be a part of global research efforts, external funding sources are critical to contribute to building capacity, engaging talented scientists, and stimulating local and national investments. These sources include funding from partnering nations through science programs, sectoral programs (e.g., agriculture or health), development programs, international organizations, the private sector, and foundations. Potential U.S. collaborators and funders come from all sectors of the U.S. S&T enterprise, including: 1) federal agencies; 2) universities; 3) scientific societies and science academies; 4) foundations and the private sector; and 5) distributed networks.

U.S. Federal Agencies

Many researchers in ESPs seek grants and funding from U.S. government agencies. However, available grants are competitive and limited. Navigating these complex funding processes can be difficult, especially for ESP applicants who are not proficient in written English or are unfamiliar with the norms and expectations of application reviewers.[148]

Several U.S. agencies, each guided by its own authorities and program specifications, support research with ESP scientists. In some cases, researchers are able to obtain funding through joint initiatives at the NSF, such as the National Science Foundation–National Research Foundation of South Africa joint research program on biodiversity.[149] In such bilateral partnerships, each country is responsible for supporting its own researchers—thus, these types of partnerships can be difficult for ESPs with fewer government resources allocated for research. The Office of Naval Research (ONR) Global has funded international scientific research on a smaller scale with impressive impact.

USAID regularly engages with researchers in ESPs on scientific research from aid and development perspectives. One example of a notable USAID-supported program is the Partnerships for Enhanced Engagement in Research (PEER), which supports scientists in developing countries and pairs grantees with U.S.-based scientists.[150] PEER awards provide researchers up to $200,000 and support projects that address key data or evidence gaps or test implementation research with the goal of informing local or international policies.[151] PEER's December 2020 grantee cohort includes a research project to improve agriculture management and agroforestry with farmers in the Dominican Republic, a project to develop technology for energy storage in Tanzania, and a project to address gender inequality in the STEM fields and sanitation in Malawi, among others.[152] The PEER program, administered by the National Academies of Sciences, Engineering, and Medicine, is able to leverage the scientific excellence, capacity, and talent of many U.S. agencies, including NASA, the NSF, the NIH, the National Oceanographic and Atmospheric Administration, and the U.S. Geological Survey.[153]

One U.S. agency with wide-ranging support for ESP researchers and collaborations with ESPs is the NIH. A major venue within the NIH for partnership with ESPs for global health is the Fogarty International Center (FIC). Established in 1968, the FIC seeks to build partnerships between the United States and international health institutions and to advance global health research to "reduce the burden of disease, promote health, and extend longevity for all people."[154] The FIC offers a variety of grants for which internationally based scientists can apply across a variety of research topics, including infectious and noncommunicable diseases, occupational health, biodiversity, and mobile and digital health. In addition, the FIC offers several grant programs for career development, many of which are targeted at researchers located in designated LMICs. Many of the trainees of FIC career and research programs have continued to collaborate with their U.S.- and LMIC-based mentors after completing their fellowships, contributing to important global health research and discoveries, including the development of a Zika vaccine in Iquitos, Peru;[155] strengthening the pandemic response to Ebola in West Africa;[156] publishing sweeping international studies on HIV/AIDS and prompting significant changes to treatment protocols in the United States and abroad;[157] and potentially revelatory research on Alzheimer's disease in Colombia.[158]

Universities

Universities are central hubs and entry points for U.S. scientists seeking collaborators. However, the capabilities and resources of universities around the world vary significantly (see Centers of Excellence on page 27). Partnerships can take many forms and the potential for success depends on the commitment of both partners to the endeavor. U.S. universities can contribute to these partnerships in multiple ways, including direct funding support for programs; in-kind contributions, such as providing lab space, equipment, and training; and support for visiting positions for faculty, students, and postdocs.

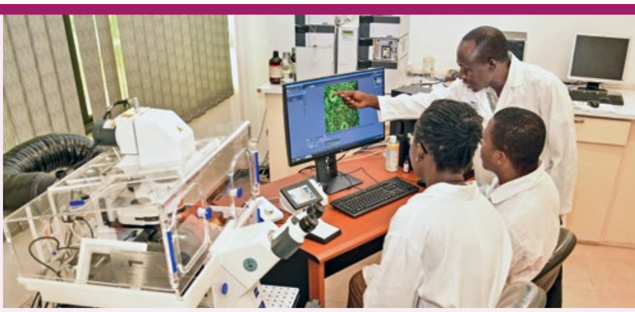
In some cases, institutions may be codeveloped and established from the ground up; in other cases, universities may partner with other universities. U.S. institution-building efforts with South Korea in the 1960s and Singapore in the 1990s are two successful models (see Codeveloping Institutions for Sustained R&D: South Korea and Singapore on page 29).

Another approach is the establishment of international satellite campuses. Carnegie Mellon University in Africa, for example, is a collaboration established in 2011 between Carnegie Mellon and the government of Rwanda. The mission of the initiative is to address the critical shortage of engineering talent trained on the African continent and to ensure that high-quality talent is ready to accelerate development in Africa for years to come.[159] Similarly, the University of Arizona (UArizona) established a network of "microcampuses" around the globe, with locations including Nigeria, Thailand, Sri Lanka, Indonesia, and Rwanda.[160] The program allows enrolled international students to obtain UArizona degrees at any microcampus location while maintaining full-time status as a student at a partner university in the country. In doing so, international students obtain U.S. graduate and undergraduate degrees without studying in the United States, thereby fostering mobility and flexibility—potentially a particularly relevant model for a post–COVID-19 world.[161] These programs engage faculty from UArizona and from the partner universities, allowing for the codevelopment and codelivery of programs and courses. With this model, UArizona is working to expand capacities and enhance relations with partner institutions across the globe. Such a model could provide more accessible education to people around the world, especially those who do not have the resources or opportunities to pursue international travel, including many women who may be unable to pursue international training due to family and childcare responsibilities.[162]

Collaborations at the university level have significant potential for developing strong and sustainable scientific capacity, facilitating scientific discoveries, and developing even stronger networks of collaboration outside the primary institutions. Such collaborations not only have the potential for capacity building, but for the exchange of ideas, knowledge, and, in some cases, personnel.

Centers of **Excellence**

Centers of excellence, defined broadly as research or training institutions, universities, laboratories, science museums, libraries, or other such institutions, are hubs for science and innovation in the United States, ESPs, and around the world.[163] In Africa, the World Bank in collaboration with African governments and the African Association of Universities established the African Higher Education Centers of Excellence Project (also known as the ACE Impact Project) to develop several high-quality institutions for training postgraduate students in the sciences. These centers are seen as a way of promoting regional specialization and collaboration and include the West African Center for Cellular Biology of Infectious Pathogens (WACCBIP) at the University of Ghana, which has emerged as an important hub for research on malaria and, more recently, COVID-19.[164]



Graduate interns conduct research experiments at WACCBIP. Photo courtesy of WACCBIP.

Centers such as these are clear contenders for U.S. scientists and institutions seeking to partner with ESPs in advanced scientific endeavors, as they are often home to top-tier talent, as well as top-quality scientific equipment that allows for in-country data collection and analysis.

Scientific Societies and Science Academies

Scientific societies and science academies, as well as the bodies that work to connect them regionally and internationally, are key for science engagement in the United States and with ESPs alike. While these organizations are typically dependent on other sources for program funding, they can leverage their breadth of membership, their global vision of science, and their expertise, in addition to their strong relationships with federal and private funders, to support fostering and expanding research partnerships with ESPs.

Many leading scientific societies, including the American Association for the Advancement of Science (AAAS), American Chemical Society, American Physical Society, American Geophysical Union, IEEE, and Society for Neuroscience (SFN), are based in the United States and prioritize global membership and engagement, including from ESPs. Scientific society conferences, publications, and programs are, in many cases, intended for a worldwide audience, as they seek to foster and disseminate the best science in their respective disciplines. In doing so, U.S.-based societies are natural partners with ESPs along with other international members and program participants.

SFN, as one example, has thirty-six thousand members from more than ninety-five countries and offers reduced membership fees and alternative routes to membership for residents of developing countries.[165] SFN, which also receives financial support from nongovernmental organizations (NGOs), administers a year-long online training program for early career researchers in Latin America and the Caribbean.[166]

National science academies are also excellent facilitators of collaborations with ESP scientific talent and provide opportunities for science policy collaboration.[167] They serve as important hubs for recognizing in-country scientific excellence and negotiating potential collaborations and partnerships. TWAS, for example, recognizes the most impressive scientific talent from the developing world.[168]

The African Science Academies Development Initiative (ASADI) program, launched in 2004, was a ten-year program of the U.S. National Academy of Sciences, funded by the Bill & Melinda Gates Foundation, to build and strengthen several academies of science in African countries, with major grants awarded to Uganda, South Africa, and Nigeria, and modest support provided to academies in Ghana, Cameroon, Senegal, Kenya, and the regional African Academy of Sciences (AAS). The program aimed to increase the capacity for evidence-driven, science-based policy advice for African governments.[169] To date, eighteen countries in Africa have established Academies of Science recognized by the Network of African Science Academies (NASAC), the African regional network of the InterAcademy Partnership (IAP).[170] In a final assessment of the ASADI program, the IAP concluded the program to be a significant success, especially in delivering training and networking opportunities to science academy staff and members, both within Africa and abroad. Initially, the goal was for thirty African academy staff to undertake training supported by the ASADI program, which would provide skills to aid staff in strategic planning, thus strengthening local secretariats. This goal was far exceeded, with more than seventy people participating in the training. Many of these individuals then went on to train others, resulting in more than one hundred people,

Codeveloping Institutions for Sustained R&D: South Korea and Singapore

South Korea

After the Korean War, the United States collaborated with the Korean government on a shared goal of institution building, including the development of science universities. In 1970, Chung Kun-Mo, a Korean research professor at MIT and later at the Polytechnic Institute of Brooklyn, submitted (on the advice of the then administrator of USAID, John Hannah) a proposal to the Ministry of Science and Technology in Korea to establish a graduate school for S&T in an effort to prevent brain drain. The proposal was accepted, and Chung and the Korean government submitted funding requests to USAID with the support of Korea's then president, Park Chung-Hee.[171] In 1971, USAID contributed $6 million (the equivalent of $38 million today) to establish the Korea Advanced Institute of Science (KAIS), which later combined with the Korean Institute of Science and Technology (KIST) to form the national research university KAIST (formerly the Korea Advanced Institute of Science and Technology) in 1981. The two would later split into two separate institutions, KIST and KAIST, in 1989 due to different research philosophies. KAIST's development was advised by Stanford University's then provost, Frederick Terman, whose "Terman Report," codeveloped with significant input from Chung, served as a blueprint for the design and building of KAIST's science and engineering research and education programming.[172] Now, as a world leader in S&T, KAIST is working to continue capacity building, this time as a donor, including a $95 million loan to Kenya to establish an advanced S&T center known as Kenya-KAIST.[173]

Singapore

Universities have also played a role in directly supporting institution building. As one example, MIT has committed significant resources to institution-building efforts in several countries, including Singapore. Like South Korea, Singapore quickly emerged as a leading innovator in S&T due to its government's strong support for R&D. When MIT's first Singapore institution-building project began in 1999, Singapore was an ESP, its GDP an estimated $86.28 billion compared to $372.9 billion in 2019.[174] The project, called the Singapore-MIT Alliance, was a collaboration between MIT and Singapore's top two technical universities, the National University of Singapore and Nanyang Technological University. Before the project's launch, MIT faculty visited Singapore in 1998 and spent four months developing recommendations for building a strong collaboration with university administrators and faculty in Singapore, including support for exchanges of students, faculty, and courses.

The success of such partnerships, and the extent to which they are fully realized by the ESP, can depend on the investment and commitment of that country's government. Both South Korea and Singapore committed significant government resources to R&D; thus, the United States could trust that its investments in these institutions would lead to strong scientific partnerships long-term. Today, despite stated commitments, many ESPs have not made the necessary financial investments to develop domestic scientific enterprises.[175] U.S. support for current ESPs could aid in securing partner government commitments to develop science capacity, leading to more promising future scientific collaborations and advancements.

including academy staff and council members, benefiting from this one training program and contributing to a more sustainable science academy workforce.[176] The report also emphasizes the importance of continued capacity-building efforts to further strengthen established institutions, aid in the establishment of new academies, and support continued collaboration across the continent and the world. In addition, the academies must address the lagging participation levels of women scientists in their memberships.[177]

Science academies continue to have a role in promoting science, engineering, and medicine. A recent IAP-coordinated report speaks to the value that academies can have as resources for policy-makers. Further, it calls for continued support and facilitation of academy programming and capacity-building efforts for both early career and established scientists.[178] By supporting such priorities, the United States could strengthen and foster relationships with top-tier scientific talent globally.

Academies of Science (and their regional branches) recognized by the IAP (see Appendix C: Regional Science Networks on page 57) have significant potential for building academy-to-academy relationships that can increase scientific capacity and share best practices.[179] The Global Young Academy (GYA), which recognizes scientific excellence in early career scientists, is an important body for connecting with young voices and the next generation of scientific capacity builders.[180] Expanding mentorship programs that pair early career scientists and senior scientists (e.g., members of the National Young Academies and senior members of the U.S. National Academy of Sciences) hold significant potential as an approach for sharing knowledge between generations and fostering future scientific leaders.[181]

Science academies may provide a strong platform for establishing and strengthening collaborations with researchers in ESPs. One historical example: the Committee on Scholarly Communication with the People's Republic of China, supported by the U.S. National Academy of Sciences, was established in 1974 and facilitated early visits and collaborations by U.S. and Chinese scientists as China and the United States reestablished diplomatic relations.[182]

Scientific societies can also play a key role in fostering diplomatic relations. For example, the AAAS Center for Science Diplomacy, established in 2008, engages with scientists around the world to build bridges wherever strained diplomatic relationships exist between countries. One of these efforts was focused on building cooperation between the United States and Cuba. In 2014, a delegation of scientists affiliated with AAAS met with scientists at the Cuban Academy of Sciences and engaged in discussions that led to the signing of an MOU to advance scientific cooperation between the two institutions.[183] Since that time, the two countries have held multiple workshops on commonly shared concerns, including on the topics of cancer, vector-borne diseases, and neuroscience.[184] These workshops aim to bring leading scientists together and create opportunities for information sharing and future collaboration.

Foundations and the Private Sector

Scientists working in ESPs often apply to nongovernmental funders, private foundations, and companies for support of their research endeavors. Philanthropies in particular are well-suited to direct funds toward scientific collaborations because, in comparison to federal agencies, they are subject to fewer

Capacity Building and Foundations: Rockefeller and Bill & Melinda Gates Foundations

U.S. foundations have a long history of funding capacity-building initiatives internationally across a variety of scientific disciplines. The benefits continue to be seen to this day. For example, the Rockefeller Foundation's funding of applied agriculture research in the early twentieth century included the launch of the International Rice Research Institute (IRRI) in the Philippines, whose work helped prevent widespread famine in Asia following the end of World War II.[185] IRRI is only one of the agricultural research centers now distributed across the developing world that support research to promote food security internationally, including in the United States, through innovative agricultural research. The institute is managed under the collaboration CGIAR, which the United States continues to support with federal funding from USAID and with funding from the Bill & Melinda Gates Foundation (see Mission-Driven Networks on page 33 for further discussion of CGIAR).[186]

Foundations are also widely considered to have been instrumental in establishing modern public health practices. In 1909, John D. Rockefeller contributed $1 million to establish the Rockefeller Sanitary Commission for the Eradication of Hookworm in the American South, which then served as a model for building public health infrastructure in the United States and abroad. In 1913, the Rockefeller Foundation launched its International Health Division, which preceded the founding of the WHO as the most important global health body.[187] It took the initial hookworm initiative global and then expanded to research other prevalent threats, including malaria and yellow fever, and build medical education capacity abroad—including through establishing permanent government public health structures and public health education programs.[188] Today, Rockefeller still provides significant funding for global health issues, such as committing $20 million to disease surveillance programs, including the Mekong Basin Disease Surveillance Project in Southeast Asia and the East African Disease Surveillance Network.[189]

Since its founding, the Bill & Melinda Gates Foundation has become a top funder of international global development efforts, offering significant support for initiatives in Africa. In 2004, the U.S. National Academies received funding from the foundation to launch ASADI, which sought to develop and strengthen the capabilities of African science academies to provide scientifically driven advice to government officials and policy-makers, especially to improve issues around public health.[190]

Today, the Bill & Melinda Gates Foundation provides funding for a vast array of programs across scientific disciplines and development goals. In 2003, the foundation launched the Grand Challenges in Global Health initiative, which started with a commitment of $481.6 million for projects focusing on fourteen major scientific challenges in global health, including vaccine development, development of treatments and preventative methods for vector-borne diseases, and engineering crops to more effectively provide nutrition to populations.[191] The foundation is one of the main U.S. partners in Grand Challenges, "a family of initiatives fostering innovation to solve key global health and development problems."[192]

restrictions and regulations on how funds may be allocated and used.[193] Their grants can fund capacity-building efforts, including training programs, equipment, travel, and activities often not funded by federal agencies (see Capacity Building and Foundations: Rockefeller and Bill & Melinda Gates Foundations on page 31).[194] Foundations and companies, on the other hand, often have more flexible financial resources and more discretion to develop and administer programs.

Research initiatives supported by R&D-driven companies and foundations can support opportunities for the use of newer technologies in addressing global research challenges. For example, the Google Earth–supported project Wildlife Insights is a collaboration among conservation organizations using Google's artificial intelligence (AI) technology to understand global biodiversity trends and assist with the development of conservation policy.[195] The open-source platform provides access to better data for researchers and policy-makers across the world.[196]

Nonprofits and nongovernmental organizations can also play a key role in supporting ESP researchers. As one example, the nongovernmental organization the Pew Charitable Trusts supports a fellows program in the biomedical sciences for postdoctoral students from Latin America.[197] Fellows supported by the program receive funding to go to the United States for postdoctoral training. Pew Latin American fellows contribute to research whose findings are important to U.S. citizens as well; for example, three Pew-funded researchers supported in the 2021 class of fellows are researching the mechanisms that contribute to the causes of Alzheimer's disease.[198]

Foundations and companies have significant capacity to support expansive research studies and to pioneer new technology and innovation. As these groups seek to build more robust R&D initiatives and reach new talent and new markets, collaboration with researchers in ESPs and support of capacity-building efforts in ESP countries should be a priority.

Distributed Networks

Distributed networks of collaborators can be fluid in leadership and entry points—they often involve various types of support from government agencies, universities, scientific societies, foundations, and other NGOs. They present a rich entry point for scientists and policy-makers to engage with a variety of partners, scientists, and types of research.

Often, the research conducted through these networks is global in scale and requires data collection and analysis to be conducted worldwide. For example, UN-supported international research initiatives such as the International Panel on Biodiversity and Ecosystem Services and the IPCC produce global assessments that rely on data and findings from all nations to inform international policy on shared natural resources.[199]

Mission-driven networks, which mobilize scientists to address urgent global and local issues, create opportunities for scientists interested in similar issues and topics to form collaborations at peer-to-peer levels and share data for all to use. CGIAR and H3Africa are two examples of networks that bring together scientists from around the world to work toward a common goal (see Mission-Driven Networks on page 33).

Mission-Driven Networks: Mobilizing Scientists Worldwide to Address Global Challenges

CGIAR

For fifty years, CGIAR has supported research and innovation to end hunger and food insecurity, with current research initiatives focused on transforming food, land, and water systems amid the pressing climate crisis, primarily in the Global South.[200] The network connects fifteen independent, nonprofit research organizations around the globe, each with individual research initiatives that are part of the CGIAR research portfolio.[201] The network was initially founded as the Consultative Group on International Agricultural Research in 1971. At its founding, U.S. membership included both U.S. government representation through USAID and several U.S. foundations, including the Ford and Rockefeller Foundations.[202] The United States, both through the government and through philanthropies, has consistently been a top funder of CGIAR over the past decades.[203]

From 2017 to 2021, the CGIAR portfolio focused on two research challenges: innovation in agri-food systems and global integration, which frames the work of agri-food systems within broader systems such as health, climate change, policies, institutions, markets, as well as water, land, and ecosystems.[204] CGIAR also conducts much of its research with significant attention to gender inequities and disparities.[205]

CGIAR's impact is measured along three main axes: 1) science-based innovation and the development of technologies and knowledge products; 2) targeted capacity development, including at the individual and organizational levels; and 3) advice on policy, including strategy advice for businesses, institutions, and public policy sectors.[206]

Researchers at the International Center for Tropical Agriculture (CIAT) bean gene bank at the Kawanda research station in Uganda. Researchers use the beans to breed more resilient varieties that will help ensure food security for future generations. Photo © 2016 by CIAT/ GeorginaSmith.

Impacts are tracked on the CGIAR results dashboard, including assessments of contributions to relevant SDGs.[207]

In mid-2021, CGIAR published its *2030 Research and Innovation Strategy*, which will support a systems-level research approach to food, land, and water.[208] This work will build on CGIAR's portfolio to meet the challenges of an increasingly dynamic world, working with partner research institutions and scientists to capitalize on the capabilities and talent of its expansive network to achieve the UN's SDGs. CGIAR's 2022–2024 Investment Prospectus describes its strategy for supporting this innovative research in the Global South by pooling its funding resources and allocating funds to research in key impact areas, including nutrition, health, and food security; environmental health and biodiversity; gender equality, youth, and social inclusion; poverty reduction, livelihoods, and jobs; and climate adaptation and mitigation.[209]

H3Africa

The H3Africa collaboration is a network that fosters genetic research and collaboration among African researchers on the continent to improve African and global health.[210] As scientists in other parts of the globe revolutionized genomic research, African countries were largely left behind. The formation of H3Africa in 2011 sought to address this deficit by directing research funds toward inequities in health and economic well-being in Africa and internationally.[211] In addition to supporting fundamental and basic science research on communicable and noncommunicable diseases, H3Africa also seeks to support capacity-building initiatives to develop scientific infrastructure, resources, training, and ethical guidance on health research.[212]

The H3Africa consortium is a network of research sites located across Africa with funding support from the NIH, Wellcome Trust, and the African Academy of Sciences. H3Africa's endeavors include research projects, collaborative research centers, and biorepositories. Working groups provide guidance and oversight on administration, such as management of biorepositories and community engagement, as well as guiding research directions and priorities (e.g., on cardiovascular diseases, environmental health, HIV, and AIDS).[213] H3Africa has made substantial progress toward developing "Principles on Ethics, Governance, and Resource Sharing," part of an effort to combat "parachute science" and exploitive human subjects research.[214]

Research from H3Africa has led to important insights into the earliest humans and into understudied diseases, such as sickle cell disease, a genetic disease that impacts primarily those of African descent, including an estimated one hundred thousand Americans, with an incidence of one case for every 365 Black or African American births.[215] As H3Africa expands its sickle cell research, as well as its research into other genetic diseases impacting people of African descent, the findings and potential therapies may play a significant role in alleviating this disease burden for all global citizens of African descent, including Black Americans.[216]

The United States supports H3Africa through several NIH institutes and centers, including the NIH Common Fund, the National Human Genome Research Institute, and the FIC.[217] These grants are intended for African-based researchers and institutions to promote a strong genetic research community on the continent and with the African diaspora.[218] This support provides opportunities for both peer-to-peer collaborations and institutional relationship building with African researchers and institutions.

Embedding Equity and Transparency for Collaborations with ESPs

So long as scientists work to make new discoveries and meet global challenges, collaborations between U.S. and ESP researchers will be in the interest of the United States, ESPs, and the world. As scientific research becomes increasingly global, international collaborations will be key to unlocking future scientific discoveries in all disciplines. The regional workshops held by the CISP initiative made clear the immense promise of research conducted in partnership with ESPs.

These collaborations should be based on shared goals and mutual commitments to high-quality science, be rooted in shared scientific priorities, and be mutually beneficial for all collaborators. Furthermore, the United States must promote equity in collaborations with ESPs. The United States must respect the local contexts in which ESP researchers are working, including the merit and valuable perspectives that researchers in ESPs bring to the table and the realities of available resources. Concerns from all partners must be addressed if sustainable, long-term collaborations are to be successful. In particular, the United States should seek to engage and support the involvement of women and other underrepresented groups in its collaborations with ESPs. Gender parity is a consistent issue in STEM across the world. UNESCO data show that women comprised less than 30 percent of all researchers worldwide in 2014–2016.[219] As the United States invests in collaborations with ESPs to build capacity and develop the global STEM workforce, the United States would be remiss not to put gender parity at the forefront both for the United States and with potential collaborators.

As the CISP initiative held workshops with ESP researchers, the issue of lack of equity or fairness in scientific collaborations was frequently raised. Although workshop conversations were wide-ranging and some issues were specific to single disciplines, localities, or countries, the workshops surfaced common themes that threaten to weaken current and future scientific collaborations:

Defining research priorities: The United States is a main funder of many U.S.-ESP collaborations and is therefore often in a position of defining which research questions are answered. In some cases, these projects are not top priorities for the ESP country, but ESP researchers may feel obligated to participate so as not to jeopardize funding for their laboratories and personnel.

Accessing funding: Even when U.S. funding that matches ESP priorities is available, it may not be accessible. Complicated and nuanced public and private grant-making systems and language barriers can be major obstacles for ESP scientists applying for funds. Well-established scientific enterprises, with accessory support from administrators, are often in a better position to win competitive grants.

Participating in data collection and analysis: A lack of local scientific capacity and infrastructure, when not understood and addressed, can limit ESP scientist participation in the research projects. “Brain drain” can further impair ESP involvement if top local scientific talent consistently and permanently leaves for more established scientific enterprises. The UNESCO Open Science movement could be a key opportunity for making data analysis more accessible to researchers in ESP contexts (see UNESCO’s Open Science Movement on page 37).

Benefiting from research findings: Once scientific findings have been reported, ESP researchers may not equitably benefit from them. This effect can manifest in myriad ways, including unfair authorship attribution, a lack of intellectual property (IP) ownership, and inequitable application of research findings.

Diverse and inclusive participation: ESP researchers described obstacles to full participation in science as particularly pronounced for women, racial and religious minorities, and early career scientists. To ensure success, efforts must be made to consider the specific motivations and barriers faced by these groups.

The ongoing COVID-19 pandemic has forced the world, including its scientists, to adapt to a new way of operating. Nearly overnight, it has produced a vast expansion of our ability to hold productive, digitally based, remote workshops and conferences. It has also generated many new, small-group, virtual meeting collaborations. These new abilities make possible many new types of collaboration that can seamlessly include scientists and engineers in ESPs—greatly facilitating many of the goals of this report.

Progress toward diversity and inclusion in the scientific enterprise is an essential component of building scientific partnerships. For each of the mechanisms described in this report, policies should be created or bolstered that promote gender equity in scientific research endeavors, both in the United States and in ESPs. Particular attention must be paid to the inclusion of young researchers, who are the future of science, technology, and innovation and tend to include greater numbers of women and members of underrepresented minority groups. Truly excellent science cannot be conducted if it is not open and inclusive of all backgrounds. Talent in science can stem from anywhere and is not related to race, ethnicity, religion, or other aspects of identity or affiliation.

In the United States, the disruption caused by the pandemic is occurring among other major shifts, including a renewed attention to the need for racial justice; an increased understanding of the value of diversity, equity, and inclusion; and widespread yet unequal access to digital infrastructure (see Justice in Science on page 38). All of these developments have implications for the workings of the U.S. scientific enterprise, and each of them presents the scientific and academic communities with a unique opportunity to rethink and reinvent how research can be conducted, shared, and applied to be more inclusive, more collaborative, more transparent, and more significant. Although further discussion of these broader trends is beyond the scope of this report, creating more accessible methods of collaboration and information exchange between established and emerging science partners will help build strong relationships that can accelerate the work of solving the pressing challenges of today and the future.

UNESCO's **Open Science Movement**

The Open Science movement, which seeks to make scientific research and data more accessible and transparent, is increasingly gaining traction with the international community. The project could be of particular importance to ESPs if it can make essential data more accessible for developing technological innovations and sustainable development strategies that allow for economic development.

In 2019 at the fortieth session of the UN General Conference, 193 member states tasked UNESCO with conducting a study to develop a set of international standards for open science that UNESCO member states could then adopt in 2021.[220] These standards would achieve three goals: 1) make data more accessible through open access; 2) make data more reliably collected (open data); and 3) more actively engage stakeholders in the data collection process (open to society).[221]

In preparation for the implementation of the recommendation in 2021, UNESCO assembled an international advisory group and held extensive consultations with regional representatives from the Americas, Europe, Asia and the Pacific, Arab states, and Africa, in addition to consultations with regional and global bodies, including the Global Young Academy.[222] UNESCO engaged and partnered with stakeholders across a variety of sectors, including international science organizations, science academies, research institutes, universities, libraries, citizen science organizations, publishers and data repositories, and the UN system to develop its guidelines and protocols.[223]

While fostering important international connections to garner support for the Open Science project, UNESCO also surfaced many obstacles to the implementation of its Open Science guidelines. These include a lack of infrastructure for, and expertise in, data processing, storage, and analysis in some regions and contexts; lack of access to journal articles; and the need to shift norms and perceptions of open science in traditional academic and research institutions.[224] U.S. input into the initiative was complicated by the absence of the United States as a member of UNESCO. As the largest contributor to global scientific productivity, the United States has enormous influence on the norms and processes of scientific research. Several institutions in the United States, including the NIH, NSF, and the Bill & Melinda Gates Foundation, are committed to, and in some cases already mandate, open publication, open data, or both and are supportive of the UNESCO Open Science initiative.[225] However, major challenges still exist, including costs associated with data storage and publication, which can be significant barriers for researchers in low-resource institutions.

Following an extensive and transparent process to develop the Open Science guidelines, representatives of member states met to negotiate the final wording of the recommendation in May 2021. At the UNESCO General Conference held in November 2021, the recommendation was adopted by all 193 member states.

Though many challenges still remain in implementing the recommendation, UNESCO's momentous success in gaining widespread approval for its Open Science guidelines could be revolutionary for ESPs seeking to leverage scientific investment and technological innovation as a means of development. Countries with strong scientific enterprises should play a key collaborative role in developing this infrastructure and capacity for the future.

Justice in Science

While dealing with the COVID-19 pandemic, the United States has also been reckoning with a renewed call for racial justice prompted by, among other deaths, the May 26, 2020, killing of George Floyd by police in Minnesota.[226] This crime spurred a global outcry for systemic change, as the history of centuries of oppression and decades of violence against racial minorities joined with growing frustration at the disproportionate impacts of COVID-19 on Black, Native, and Hispanic communities.[227]

Recent circumstances, while not novel to the era, have pressed a new sense of urgency and a growing demand for diversity, equity, and inclusion within the U.S. scientific community. These efforts should extend to considerations of building equity in international collaborations as well.

In doing so, U.S. collaborators should also bear in mind the history and broader context that inform their collaborations. In many regions of the world, the impacts of colonialism continue to this day.[228]

Patterns of Collaboration: Former colonies tend to collaborate with their colonizers, including in science.[229] The reasons for this prevalence in collaboration may be based in practicalities, such as shared languages and institutional ties, that are mutually beneficial. At the same time, fraught histories that inform the relationships between high-income countries and LMICs, as well as the ever-changing dynamics within countries, can pose challenges for building sustainable and equitable partnerships. Although most ESPs are not former colonies of the United States, other colonial histories may still pervade scientific practices and influence the shape of collaborations between U.S. and ESP researchers.

Present-Day Mistrust: In some cases, histories of unethical research can have lasting repercussions in the minds of ESP researchers and study participants. As one example, in the 1950s, U.S. researchers conducted trials of birth control pills on women in Puerto Rico, a former U.S. colony and current unincorporated U.S. territory. In these trials, the researchers dismissed side effects reported by the study participants and failed to inform them that they were part of a clinical trial or that the drug they were taking was experimental.[230] Decades later, many of these women continue to decry the role they unknowingly played.[231]

Breakdowns in Collaborations: In times of crisis, historical legacies can present major challenges to successful partnerships. In May 2021, Mount Nyiragongo erupted in the Democratic Republic of the Congo, killing dozens and prompting an estimated one million residents to flee.[232] Prior to this disaster, the Goma Volcano Observatory's leadership was accused of embezzlement, which prompted the World Bank to pull its funding. This decision left staff volcanologists without Internet connections for remote sensors or fuel for transportation, inhibiting their ability to warn of impending eruptions. Following the disaster, staff at the observatory not only condemned the corruption of Congolese leadership but also accused the World Bank's European leadership of taking a "neocolonial" approach that contributed to the eruption's devastating effects.[233]

Scientists are working to develop best practices for ensuring ethical conduct in future research.[234] The ongoing movement for racial justice in the United States presents a unique opportunity to rethink how the scientific enterprise can restructure international scientific collaborations to meet this goal.[235]

Mechanisms for Action

As research partnerships with ESPs are an increasingly important component of advancing science, addressing global challenges, and building the future global S&T enterprise, we recommend that:

1. The United States should actively foster and build collaborations with ESPs, including by welcoming ESP researchers, particularly those seeking graduate education, to U.S. universities and research institutes.

2. Through its research and education collaborations with ESPs, the United States should continue to contribute to building global research capacity and the global STEM workforce.

3. Collaborations with ESPs should reflect values of transparency and equity.

As described in the section on U.S. Collaborators for ESP Engagement, the United States engages with ESPs in many venues, including through the U.S. government, universities, scientific societies, academies, R&D-focused companies, and foundations. The realization of these three recommendations is often linked in the process of funding, design, and implementation of programs and initiatives. Therefore, the mechanisms presented below, organized by the various U.S. partners, contain actions that address all three goals.

The following mechanisms for action to build stronger, more equitable collaborations with ESPs are directed toward U.S. stakeholders. However, just as these recommendations were workshopped in partnership with ESP scientists and policy-makers, they should be implemented in partnership with the same to ensure mutual benefit.

1. Federal Agencies

1.1 *Federal funds for U.S.-ESP collaboration should be increased and should prioritize research that is high quality, simultaneously rooted in both ESP scientific priorities and in U.S. research goals. When possible, grants should seek to include funds for travel (for both principal investigators and lead researchers), open access publishing fees, and conference participation. Funding programs should be built to encourage participation from young, women, and underrepresented scientists.*

1.2 *The United States should support enacting novel flexible funding mechanisms. Given the scale of scientific challenges facing the world and the changing landscape of scientific collaboration, this may require revisiting the funding* *authorities of the various agencies. Novel mechanisms could include:*

- Allowing awards in support of the work of international principal investigators, as is currently the case for the NIH's funding of global health research and ONR Global.
- Expanding bilateral and multilateral scientific research collaborations between U.S. agencies and their ESP counterparts, as in the case of NSF joint funding initiatives.

1.3 *The United States should increase the accessibility of federal grants for which researchers in ESPs are eligible, potentially by streamlining application processes, more clearly issuing calls for proposals, and by performing training workshops abroad or virtually to guide ESP researchers through U.S. systems.*

U.S. agencies could play an important role in expanding funding support of ESP scientists and institutions. With a few exceptions, such as the NIH and ONR Global, most U.S. agencies cannot directly fund scientists abroad. U.S. agencies and the U.S. Congress should consider revising such policies to support and engage more directly with scientists working on shared scientific priorities and goals, such as climate change. This could be especially important for ESPs where government support is currently insufficient for funding science to enable the development of scientific capacity and promote new knowledge in key fields, such as climate-related sciences.

When U.S. and ESP scientists establish a collaboration on a topic of shared interest, the research questions of each may differ in ways that can be complementary or divergent. Without agreement from all parties on how to proceed with designing the research agenda and methodologies to meet goals on both sides, projects can be disjointed and ineffective.

Identifying shared research goals from the start of the collaboration helps to ensure all partners benefit and can pursue research that will address priorities and goals on both sides. Many regions of the world have established research priorities that fall in line with regionally established development goals or with the UN sustainable development goals (SDGs) as outlined in Agenda 2030. Working within these frameworks may help collaborators to align their research.[236] Where ESP regional or national research priorities align with those of the United States, U.S. federal agencies could seek to make additional funding available and streamline funding structures. Identifying well-matched collaborations may involve looking beyond the most well-established labs or scientists. Research centers that have emerged as strong scientific entities within ESPs tend to attract a majority of funding, which can leave new and developing research hubs struggling to become established.

1.4 *The U.S. State Department should streamline visa application processes and increase visa numbers for ESP scientists at all training and career levels. U.S. agency-administered fellowship programs that provide opportunities for ESP researchers to work in the United States and for U.S. scientists to work in ESPs should be continued and expanded.*

1.5 *In cases where infrastructure-building is required, U.S. funding agencies should pursue scoping activities prior to allocation of funds if capacity is not already known. Financial or in-kind contributions from ESP governments, often required, should always be encouraged alongside U.S. investments in ESP scientific infrastructure. In addition, the long-term sustainability of the infrastructure should be considered when planning.*

The United States must actively foster collaborations with ESP scientists. One important mechanism for doing so is making available federal funding support specifically for ESP graduate students and postdoctoral fellows pursuing education and research opportunities in the United States, especially at universities and research institutions. The relationships forged through such engagements can lead to long-lasting relationships and collaborations with tremendous benefits to all and are a key component of maintaining a robust STEM enterprise and STEM workforce in the United States. Federal agencies, such as the NSF, DOE, NIH, and NASA, and the White House Office of Science and Technology Policy should consider novel approaches to support this goal.

When working with researchers based in ESPs, U.S. collaborators, including at the institution and individual level, must understand the scientific capacity of the country or institution with whom they are partnering if they are to successfully design and engage in scientific collaborations. Within and across ESPs, capacity and talent are heterogenous. For example, the scientific capacity of the BRICS countries (Brazil, Russia, India, China, and South Africa) differs greatly from that of others in their regions.[237] In collaborating with ESPs regionally, and with stronger regional partners like the BRICS, the United States could more directly support growing calls for enhanced "triangular cooperation," a strategy the United Nations hopes will help to achieve the goals of Agenda 2030.[238] *Triangular cooperation* is

The 17 Sustainable Development Goals (SDGs) outlined in Agenda 2030 by the United Nations. Unlike the United States, many ESP research priorities are designed around achieving local and global benchmarks set by the SDGs. **Source:** iStock.com/yukipon.

Inside the ring of the Synchrotron Light Research Institute in Thailand. Photo © by SLRI.

broadly defined as involving three or more partners, with one serving as the enabler or funder (e.g., the United States), one as the provider of technical assistance or infrastructure (e.g., a BRICS country), and one as the receiver or beneficiary that expands capacity (e.g., an ESP country).[239]

For some ESP scientists, accessing necessary equipment, data, or samples can be an enormous barrier.[240] Through continued conversations between partners and through exchanges in which scientists visit one another's research spaces to better understand context, partners can work together to identify approaches that will work well on all sides.

When initiated from a foundation of peer-to-peer collaboration, projects to fund the construction of large-scale scientific facilities in ESPs promise to create opportunities for more regional and global collaboration.[241] World-class facilities attract global scientific talent, contributing to a greater circulation of ideas. Further efforts to develop centers of excellence, scientific facilities and research hubs at universities, and independent research institutions can lead more scientists from outside of the region to consider conducting their research in ESP countries, while also providing incentives for trained scientists to remain in-country to further their research.

1.6 *U.S. funding agencies should fund long-term training initiatives that build technical and methodological capacity within ESPs, including initiatives to support young researchers, women, and underrepresented scientists, infrastructure for the scientific enterprise, promotion of legal and intellectual property (IP) protections, and the development of knowledge of financial reporting requirements.*

1.7 *U.S. funding agencies should set aside funds specifically to bolster U.S. institutions' collaborations with scientists in ESPs so as to enable universities and research institutions to improve and strengthen their collaborations.*

The need for capacity building in scientific administration and management can be ongoing for both new and established collaborations. For example, institutions may not have the in-house expertise to review contractual agreements, which becomes especially important in matters of IP protection and ensuring that credit and IP ownership are attributed correctly.[242] As noted by the World Intellectual Property Organization, "the modernization of the IP infrastructures of many countries has raised expectations on how the IP system can be used to promote economic development."[243] Administrative barriers must also be considered, particularly for newer institutions that may not have the necessary staffing capacity or financial reporting experience to handle and administer large grants, or the digital capacity to store data.

While some ESP scientists return to their home countries after training abroad, the barriers of obtaining funding and support from ESP governments and universities incentivize many to remain abroad.[244] Capacity must be expanded within ESPs so that conducting excellent scientific research at local institutions and remaining in their home countries is an attractive option for scientists. In U.S. supported research collaborations with ESPs, providing specific funding to support capacity-building initiatives could be an important mechanism for fostering sustained brain circulation between U.S. and ESP partners for the long term. Thailand, for example, recognized the threat of brain drain and created the Reverse Brain Drain program in 1997 specifically to engage with the Thai diaspora and to encourage Thai nationals to return to Thailand as a part of the research community. Whether for a permanent or temporary return, this encouragement to bring trained researchers home helps to prompt the exchange of ideas, strengthen partnerships and relationships with other nations, and drive further innovation. (Thailand, for example, has invested in major national scientific facilities and is planning a fourth-generation synchrotron light facility.)[245]

2. Universities and Research Institutions

2.1 *Universities and research institutions should broaden existing international scientific exchange programs that facilitate scientific networking to include scientific opportunities for American scientists, including postdoctoral researchers and students, to work in ESPs.*

Universities and research institutions, in ESPs and the United States alike, are major hubs for researchers and emerging student talent. They provide important points of entry for launching ESP-U.S. collaborations, especially for scientists seeking collaborators who share their research goals and with whom they can begin working on an informal peer-to-peer basis. In ESPs, universities are often selected to house key research centers and institutes, as well as state-of-the-art technology and scientific infrastructure.

In addition to building peer-to-peer collaborations, networks of universities around the world can also be key access points for identifying potential scientific collaborators working on similar research questions and priorities at a regional scale. For example, the Association of Pacific Rim Universities connects universities in and along the Pacific Ocean, including in East and Southeast Asia, the Pacific Islands, South America, and the United States, to address key regional issues such as sustainable development, global health, sea-level rise and pollution in the Pacific Ocean, and gender imbalance in STEM fields.[246] Similarly, the African Research University Alliance connects strong research institutions on the African continent and is a node for researchers based in the United States and elsewhere to identify potential collaborators and ongoing work.[247] For researchers looking to identify new collaborators, platforms such as these, which have already developed collaboration networks, are valuable starting points.

2.2 *Universities and research institutions should welcome young scientists from ESPs, including to study and work as postdoctoral fellows in the United States. As these researchers return to their home countries, universities and research institutions should strengthen relationships and networks formed in the United States by identifying and removing barriers to collaboration. Doing so would promote a "brain circulation" model of mobility rather than compounding the already existing pull for ESP researchers to remain in the United States.*

As university and research institute collaborations are built, attention must be paid to strengthening them equitably so they support talent and promising scientific ideas across well-resourced and emerging institutions alike. Researchers are naturally drawn to well-resourced labs and institutions that will enable them to pursue their scientific dreams. In countries and regions without strong commitments to building sustainable science ecosystems, resident scientists relocate outside of their home country to pursue their research goals more frequently than international scientists are drawn in. This brain drain pulls trained expertise away from countries that could benefit from capitalizing on this expertise to drive science innovation and engage the next generation of the science workforce.[248]

Alongside U.S. federal agencies, U.S. universities should take steps to combat brain drain and encourage "brain circulation" for the benefit of their own research enterprises and the well-being of the global research community over the long term. For example, universities should seek funding mechanisms that support international collaborations conducted by diasporas of trained scientists from ESPs residing in the United States. These programs could be modeled on other existing programs for international exchange, such as the Knut and Alice Wallenberg Foundation's long-standing postdoctoral scholarship program at Stanford University, which funds Swedish postdoctoral researchers across scientific disciplines so they can spend one to two years in the United States at Stanford.[249]

ESP diasporas in the United States, the United Kingdom, and the European Union have been key to developing scientific capacity in their home countries.[250] Trained ESP scientists based in the United States can leverage their positions to foster long-standing collaborations and partnerships with researchers and centers in ESPs, especially when engaging with and recruiting early career researchers and graduate students. Sustained collaborations present opportunities for exchange programs between institutions, provide invaluable experiences and perspectives on both sides, and contribute to building a stronger critical mass and institutional knowledge in both contexts.

2.3 *Universities and research institutions should enact policies that work toward appropriate credit attribution for publications, accommodations for language barriers, and equitable distribution* *of IP rights gained from research collaborations between U.S. and ESP scientists.*

In the near term, universities should create policies that increase equity for ESP researchers, including by providing access to equipment and ensuring fairness in authorship and IP rights. Policy needs may vary across disciplines and contexts and should be determined in partnership with ESP researchers to ensure policy details do not unintentionally exacerbate inequities.

As one example, language barriers can meaningfully obstruct access to authorship for some ESP researchers. Many universities and research institutions provide formal guidelines for their research teams to determine authorship, while acknowledging substantial variation across scientific disciplines. These guidelines vary across institutions, as well as across scientific journals; for example, some say authors must be involved in manuscript drafting; others say authors may or may not need to directly draft or revise reports of research findings.[251] U.S. researchers tend to draft and publish their manuscripts in English. International collaborators may or may not be well-positioned to draft a scientific publication in a nonnative language, despite having contributed to or co-led the scientific research. When working internationally,

MIT-Nepal Initiative

In 2015, Nepal was struck by a 7.8 magnitude earthquake that killed or injured thousands and left tens of thousands without food, shelter, and water.[252] In the aftermath, MIT established the MIT-Nepal Initiative to bring together academic, nonprofit, and private-sector groups to pursue projects that would benefit both the people of Nepal and MIT researchers and students.[253] Further research in areas including water testing and sanitation, education, and ethnomusicology was supported by grants from various MIT-affiliated institutions, including a "solutions" grant from the Abdul Latif Jameel Water and Food Systems Lab and MIT's Deshpande Center, a grant from the Abdul Latif Jameel World Education Lab, and a Visiting Artist grant from the Center for Art, Science, and Technology at MIT.[254]

In 2018, the Nepali company Ncell sponsored MIT's Global Startup Lab, an entrepreneurship boot camp, at Kathmandu University. In another venture, an MIT water engineer collaborated with ENPHO, a Nepalese NGO, and EcoConcern to manufacture and distribute low-cost water-testing kits to improve the country's water, sanitation, and hygiene infrastructure.[255] In a 2019 article in the MIT faculty newsletter, MIT researchers involved with the initiative reaffirmed its value to the MIT research community.[256]

Patan Durbar Square in the Kathmandu Valley in Nepal. This iconic square was one of many culturally significant sites devastated by the 2015 earthquake. Photo © by Getty Images/Didier Marti.

if authorship requires writing in a nonnative language, such a policy may unintentionally result in inadequate or no authorship credit for a collaborator who was a meaningful contributor or lead designer of the research.

3. Scientific Societies and Academies

3.1 *U.S. scientific society programs that facilitate global science should be expanded to facilitate interactions between U.S. scientists and ESP scientists. Programs should include public engagement by societies and their partners in ESPs, including in primary and secondary schools and in informal settings. They should also promote knowledge of major ESP research agendas and opportunities among U.S. researchers, including regional priorities often aligned with the UN's SDGs.*

3.2 *American scientific academies and professional scientific societies should establish partnerships based on shared goals and initiatives with their counterparts in ESPs, including the GYA and the National Young Academies.*

The U.S. National Academies of Sciences, Engineering, and Medicine and the New Voices in Sciences, Engineering, and Medicine are well-established bodies with capacity to engage researchers internationally.[257] Working with the Global Young Academy (GYA) and newly established in-country branches of Young Academies around the world could lead to significant opportunities for mentorships and fostering relationships between U.S. and ESP scientists.[258] Doing so would positively feed into the greater science community over the long term, as the young ESP scientists would be able to expand their networks, open avenues for dialogue and opportunities for engagement, and build greater capacity in scientific institutions in their home countries, including enhancing the capacity of their national science academies. Another significant focus of the GYA is the promotion of women in STEM and the removal of barriers to their involvement through its Women in Science working group.[259] Thus, further support and collaboration between the United States and the GYA would open more channels for engagement with, as well as opportunities for the mentorship of, women in science.

3.3 *U.S. scientific society journals should increase the participation of researchers from ESPs in the publication process by adopting changes to policies and training programs, including processes for identifying invited papers, serving on editorial boards, reviewing submissions, and submitting for and publishing research articles. They should also seek ways to improve publishing equity, including ensuring appropriate coauthor inclusion and anticipating and working to overcome language barriers.*

3.4 *When designing programs and nominating featured speakers for international conferences, U.S. scientific societies should recruit speakers, moderators, and other scientific leaders who are researchers in ESPs, with particular attention to involving rising stars. Overall, programs should represent ESP interests. When appropriate to the topic, scientific societies should consider hosting conferences and regional meetings outside the United States or holding them as more widely accessible virtual programs. ESP participation in conferences should be encouraged, potentially through travel awards, registration fee waivers, and family-friendly accommodations.*

As scientific societies and academies work to engage internationally, opportunities for digital engagement must be carefully considered. In the past two decades, digital access has revolutionized the scientific enterprise and accelerated innovation, allowing rapid access to data and recently published studies and promoting communication among scientists around the globe. In the pandemic era, digital tools and platforms have been vital for maintaining established connections, and they have opened new opportunities to expand personal and professional networks through accessible scientific events such as conferences, panels, and lectures.[260] Some scientists suggest that all conferences, by default, should be virtual so as to be more inclusive, especially of women and young scientists, who tend to have competing family obligations and have less access to travel funds, and be more environmentally conscious.[261] The ease and low cost of "Zoom-style" meetings, dramatically advanced during the pandemic, make many new types of exchanges possible, and the many new opportunities should be fully explored.

However, digital access varies widely, both across and within countries, including within the United States. Referred to as the "digital divide," nearly half of the global population does not have access to broadband Internet. Addressing this divide has proven challenging for the private sector alone to tackle. X Development, a subsidiary of Alphabet (the parent company of Google), was unable to find a sustainable business opportunity or partners for its moonshot initiative "Project Loon," which aimed to bring the Internet to remote regions of the world.[262]

Scientists in ESPs face several barriers to access, including poor connectivity for home Internet users, significant difficulty accessing broadband Internet in rural areas, and high cost. Differences in access also have a significant gender component. Some countries in Africa, Asia, and South America report that women are 30–50 percent less likely to use the Internet than men are.[263] Additionally, many benefits of in-person conferences, such as informal meetings and networking, are difficult or even impossible to duplicate in virtual settings.

Despite the limitations of virtual engagement, the tools and strategies employed to adapt to the COVID-19 pandemic and to expand connections around the world should not be discarded. Integrating digital tools and platforms into the conduct of scientific, development, and diplomatic work could be a key strategy for building relationships, promoting capacity-building efforts, and creating more equitable access to opportunities for scientists at all career levels and in all areas of the world.

4. Foundations and the Private Sector

4.1 *Foundations and companies should fund the activities listed above for universities and scientific societies in cases where those activities align with foundation and company goals, including supporting ESP public engagement. U.S.-based foundations that work to promote development should consider basic science investment in ESPs to be an indirect but key path toward innovation and economic growth. However, doing so should not come at the expense of current investments in applied research addressing global challenges.*

4.2 *U.S.-based multinational research companies should strengthen relationships with ESP universities to encourage skills development and technology transfer from local ESP university researchers to local branches of their companies. They should also prioritize processes for hiring local scientific talent, with an emphasis on working toward diversity and inclusion.*

4.3 *Foundations should provide training for lawyers based at ESP universities and research institutions to facilitate specialized education about* *scientific MOUs, IP, and the legal aspects of establishing such formal agreements and arrangements.*

Developing legal expertise to facilitate the administrative and legal processes related to formal scientific partnerships is essential for successfully navigating collaborations. Philanthropies, with their flexibility in setting funding priorities, could play a major role in building ESP capacity in this area, a necessary element for ensuring equity in collaborations between wealthy nations like the United States and ESPs. In the listening sessions conducted by the CISP project, scientists expressed the need for attorneys with the expertise to facilitate collaborations and ensure that the ESP partner is not being exploited and has due equity in the partnership.

Foundations also have a major role to play in sponsoring fellowships for ESP researchers, especially in early career stages. Many such fellowships already exist for international scholars. They should be expanded and should explicitly encourage participation by ESP scientists.

Just as markets are global, talent can be found anywhere. Investing in sustained initiatives to develop talent pools, establish new science and tech companies and start-ups, and contribute locally to developing S&T capacity could have tremendous benefits for innovation (see Tech in Africa below). Private sector collaborators have much to gain from supporting the expansion of talent in all corners of the globe, including in emerging scientific enterprises.

Technology in **Africa**

Many U.S.-based tech companies have begun to focus their attention on investing in Africa as a growing hub of talent and innovation. Microsoft is among those leading the way. In 2013, the company launched the 4Afrika Initiative to invest in start-up companies, partners, enterprises, governments, and emerging talent. Since its launch, the program has provided support to ninety-four start-ups and fully funded sixty-four with $5.1 million in returns.[264] In 2019, Microsoft established two data banks in South Africa, becoming the first global company to provide cloud services to the continent.[265]

Also in 2019, Microsoft launched its Africa Development Center with offices in Kenya and Nigeria. The offices will serve as engineering hubs and recruit African talent to develop innovative solutions for both local and global impact.[266] Microsoft has pledged to invest $100 million in the center, which seeks to employ five hundred engineers across its two sites by 2023, in addition to forming partnerships with universities to develop a robust talent pipeline on the continent.[267]

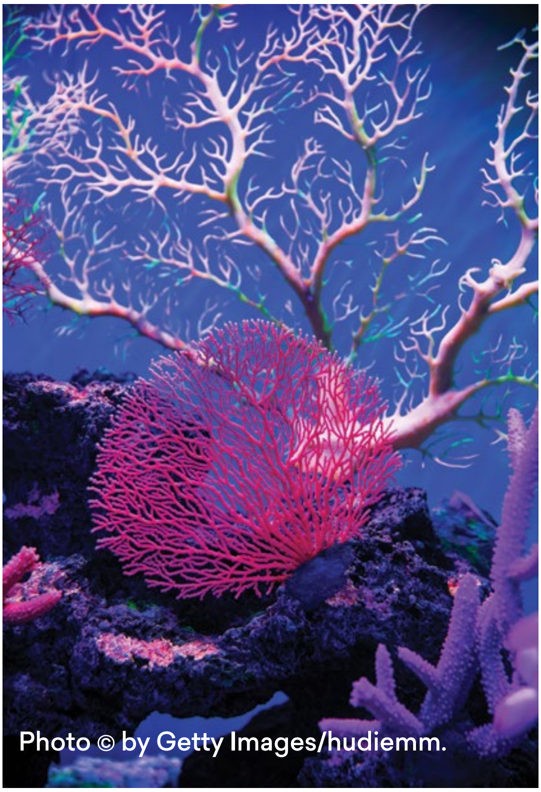
Google established its first AI Lab on the African continent in Ghana in 2019. The lab attracts talented engineers from around the world, including new talent from African universities and from the African Institute for Mathematical Sciences.[268] Scientists at the lab are able to bring African perspectives and context to inform priorities for innovation. Results include an app that farmers can use to diagnose issues with their crops (with possible additional applications for education, health, and agriculture).[269]

Conclusion

Past U.S. investments to bolster collaboration with former ESPs have proven to be fruitful, worthwhile endeavors. The many ESPs that today are looking to R&D investment as a key development strategy will be home to tomorrow's strong scientific enterprises, with presence on a global scale. To ensure its own role as a key partner in the next generation of innovation, the United States should promote relationships with ESPs and continue to be a key resource and mentor for young scientific enterprises.

In an increasingly globalized society, ESPs will be important partners for U.S. engagement. Climate change and its many cascading consequences are not confined to any one nation or region, and no one country will be able to drive the innovation and solutions needed to address these impacts. Pandemics will continue to threaten our country's health and national security and containing them will not be possible without sufficient R&D capacity and infrastructure in ESPs. Deepening our understanding of the laws of nature on scales from the subatomic to the cosmological often requires developing new tools that in turn drive technological advances. The push to extend the boundaries of knowledge is an important part of addressing current and future global challenges.

Deepening engagement with ESPs must be a priority for the United States if it is to remain a leader in science, technology, and innovation for generations to come. The United States must be careful to respect the local contexts in which ESP researchers are working, must respect the merit and valuable perspectives that researchers in ESPs bring to the table, and must ensure that all research collaborations have goals that bring mutual benefit. With considerable intentionality, thought, and attention to these collaborations, the benefits of such engagement could be immense as we look to address future challenges as a resilient and connected global community.



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APPENDIX A

Steering Committee and Working Group Members

Steering Committee on Challenges for International Scientific Partnerships

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APPENDIX B

Project Approach

The CISP project developed a preliminary set of recommendations for scientific collaborations with ESPs and identified mechanisms that the United States could use to make these collaborations more effective and equitable. These mechanisms were subsequently workshopped with more than a hundred researchers from ESPs in Africa, Asia and the Pacific, Latin America and the Caribbean, and the Middle East and North Africa in a series of soundings, including conference sessions at the 15th Annual Meeting of African Science Academies (AMASA-15) in Accra, Ghana, in November 2019; a government-led funding-agencies workshop in London in January 2020; and a series of virtual conferences held in spring 2020. On page 55, we include a map that visualizes the locations of scientists with whom the CISP project engaged over the course of the ESP project work during AMASA-15 and in global regional soundings, workshops, and panel/conference sessions.

15th Annual Meeting of African Science Academies (AMASA-15)

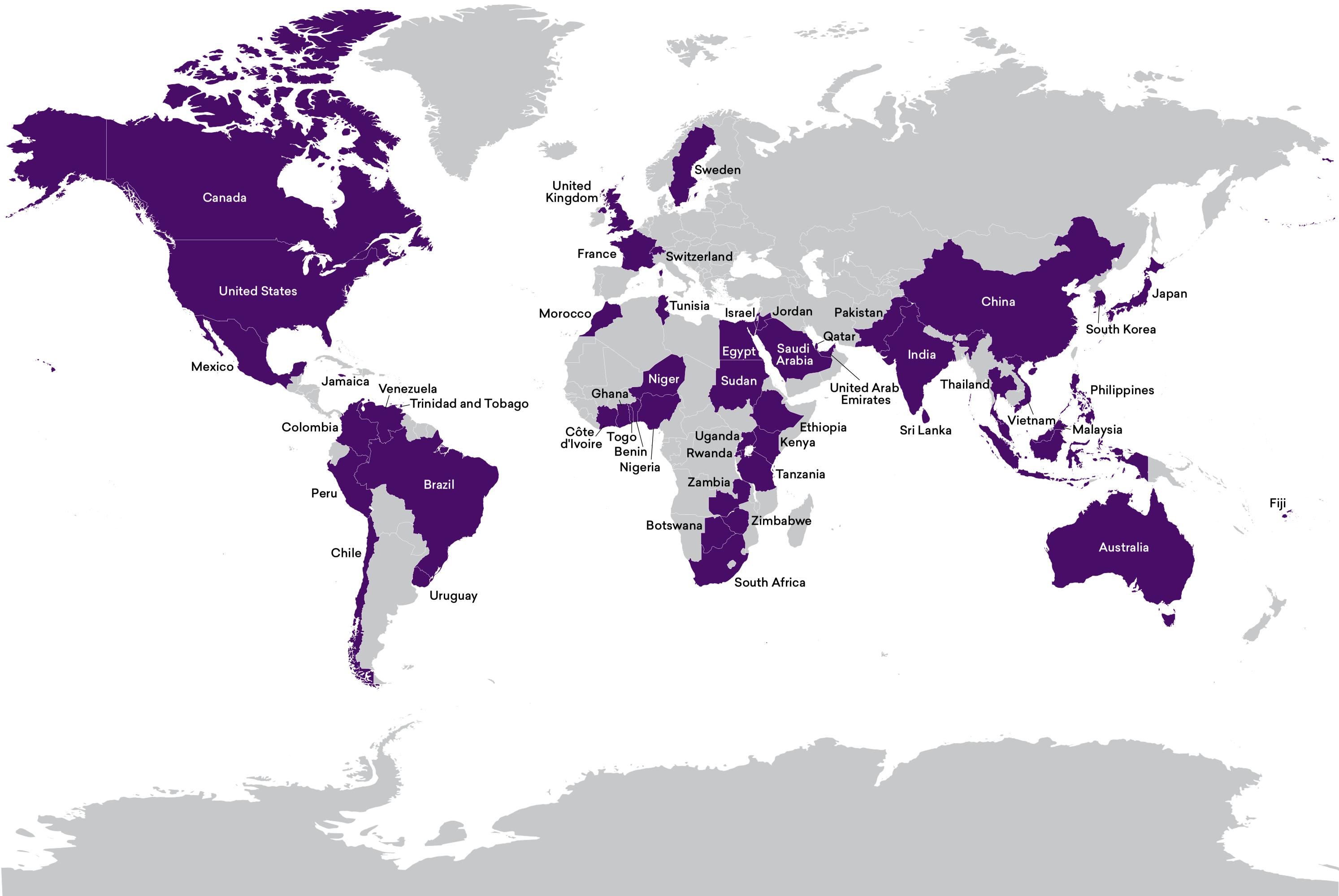
In November 2019, a delegation of the ESP working group of the CISP project attended AMASA-15 in Accra, Ghana, run by NASAC and hosted by the Ghanaian Academy of Arts and Sciences.

AMASA first arose from annual meetings of ASADI, whose inaugural convening was in Nairobi, Kenya, in 2005.[270]

African scientists, science academy presidents and officers, and science policy experts representing national, regional, and global organizations from Africa and abroad attended AMASA-15, which included a series of scientific presentations, plenaries, and interactive workshops in addition to networking events. The CISP project held two sessions at AMASA-15 to discuss African perspectives on partnerships with the United States and the West in general and to seek feedback on project recommendations.[271] These interactive sessions were the project's first international sounding exercise and contributed significantly to the final version of the recommendations presented within this report and its discussion of key themes for engagement.

Global Regional Soundings

In spring 2020, the CISP project held a series of virtual workshops with scientists, policy-makers, and science administrators in Africa, Asia and the Pacific, Latin America and the Caribbean, and the Middle East and North Africa to develop project recommendations and discuss mechanisms for strengthening partnerships



Over the course of developing the ESP recommendations and report content, the CISP project engaged with policy-makers and scientists from the countries indicated above in project soundings, meetings, conferences, panels, and informal discussions. Map image © by Free Vector Map.

Photo © by Getty Images/wiratgasem.

between the United States and ESPs. These workshops were originally intended to be held in person, but the emergence of the COVID-19 pandemic made that impossible.

With borders closed, the project adjusted to a newly virtual world, reworking its agendas and structure to hold multiple convenings with regional representatives. The virtual context provided unforeseen opportunities for engagement, including greater flexibility in scheduling meetings and inviting participants, along with multiple modalities for receiving feedback (e.g., via email, online chat, and verbal discussion). The project soundings provided a wealth of examples of successful, ongoing scientific collaborations and tangible actions for strengthening U.S.-ESP partnerships.

The final recommendations included in this report were revised extensively based on feedback from scientists, administrators, and policy-makers from the United States and around the world.

In addition to providing feedback on the proposed mechanisms presented in this report, workshop participants also provided insight into the challenges they face within their countries and regions when partnering with the United States. Although scientists, disciplines, countries, and regions face their own unique challenges, recurrent themes arose throughout these discussions.

COVID-19 and International Scientific Collaboration

The CISP project was significantly impacted by the COVID-19 pandemic, which required many regional workshops to be conducted virtually. The pandemic itself also became a project topic and has significantly shaped conversations about the future of scientific research and collaboration.

What should scientific research look like in a post–COVID-19 world? How can we use the tools and technology that have allowed scientists to stay connected during the pandemic to continue fostering connections and making scientific conferences, data, and networking more accessible? How can the scientific community leverage this opportunity to reinvent norms and rebuild its systems with diversity, equity, inclusion, and justice at the forefront? Scientists and policy-makers alike must continue to grapple with these questions even once the COVID-19 pandemic has receded.

Appendix C
Regional Scientific Networks

The InterAcademy Partnership (IAP)[272]

The IAP, which formally launched in March 2016 in South Africa, is an overarching organization that includes membership of academies of sciences, engineering, and medicine worldwide.

IAP's vision is for "the world's academies to play a vital role in ensuring that science serves society inclusively and equitably and underpins global sustainable development."[273]

The IAP has established several regional academy networks, including the Association of Academies and Societies of Sciences in Asia; European Academies' Science Advisory Council; InterAmerican Network of Academies of Sciences; and Network of African Science Academies.

Association of Academies and Societies of Sciences in Asia (AASSA)[274]

AASSA, the IAP's regional branch for Asia and the Pacific, was formed in 2012, following the merger of AASA and the Federation of Asian Scientific Academies and Societies. Its objective is to "achieve a society in Asia and Australasia in which science and technology play a major role in the development of the region."[275] AASSA serves as a forum for scientists and technologists to discuss and provide advice on issues related to S&T, R&D, and the application of technology for socioeconomic development.

AASSA is housed in the Korean Academy of Science and Technology. It currently runs two special committees: Women in Science and Engineering; and Science, Health, Agriculture, Risk, and Environment Communication.

European Academies' Science Advisory Council (EASAC)[276]

EASAC is the IAP's regional branch for the national academies of science of the member states of the European Union, Norway, and Switzerland. Its objective is to provide independent, science-based advice to policy-makers, primarily in three core areas: energy, environment, and biosciences.

EASAC is governed by a secretariat based at the German National Academy of Science Leopoldina, with an office in Brussels hosted by the Royal Academies for Science and the Arts of Belgium.

InterAmerican Network of Academies of Sciences (IANAS)[277]

IANAS, the IAP's regional branch for the Americas, was founded in 2004 and is composed of a network of academies of sciences. Its goal is to support cooperation and strengthen S&T to advance R&D, prosperity, and equality in the Americas.

IANAS supports several programs, including food and nutrition security, energy, water, women for science, science education, and capacity building.

Network of African Science Academies (NASAC)[278]

NASAC is the IAP's regional branch for Africa. Its vision is to be "the ideal science advisor and partner in the African continent," by making African science academies vehicles of positive change and by helping science enable Africa's potential and its sustainable development.[279]

NASAC supports work in four major thematic areas, including women for science, climate change, water, and science education. It also supports three major programs, including the Leading Integrated Research for Agenda 2030 collaboration with the ISC; a NASAC–German Academy of Sciences Leopoldina collaboration; and a capacity-building grants program.

International Science Council (ISC)[280]

The ISC is an NGO comprising forty international scientific unions and associations and more than 140 national and regional scientific organizations. The council was created in 2018 as a result of a merger between the International Council for Science and the International Social Science Council.

The ISC's mission is "to be the global voice for science; a trusted voice that speaks for the value of all science."[281] It focuses on three primary areas of work: science for policy, policy for science, and scientific freedom and responsibility.

Regional Office for Africa[282]

The Regional Office for Africa was established in 2005 and is hosted by the South African National Research Foundation in Pretoria.

The office aims to ensure that the voices of African scientists influence international science agendas and that international programs are guided by regional priorities. The office has four major priority areas, including sustainable energy, natural and human-induced hazards and disasters, health and human well-being, and global environmental change.

Regional Office for Asia and the Pacific[283]

The Regional Office for Asia and the Pacific was established in September 2006 and is hosted in the Malaysian Academy of Sciences in Kuala Lumpur.

The office aims to promote science throughout the Asia and Pacific region that will strengthen the voices of scientists within the region. The office focuses on five primary project areas: hazards and disasters; earthquakes, floods, and landslides; sustainable energy; ecosystem approach; and the special vulnerability of islands.

Regional Office for Latin America and the Caribbean[284]

The Regional Office for Latin America and the Caribbean was established in April 2007. It was hosted by the Brazilian Academy of Science until November 2010, followed by the Mexican Academy of Sciences until 2016; it is now based in San Salvador, El Salvador.

The office, which is led by a steering committee, has four main priority areas: sustainable energy, natural disasters, mathematics education, and biodiversity.

International Network for Government Science Advice (INGSA)[285]

INGSA is a collaborative platform that aims to enhance the global science-policy interface to improve policy at multiple levels, including subnational, national, and transnational. INGSA operates as part of the ISC and is based in the Centre for Science in Policy, Diplomacy and Society at the University of Auckland, New Zealand.

INGSA partnership organizations include the ISC, the Wellcome Trust, UNESCO, and the International Development Research Centre. INGSA operates at regional levels as well.

INGSA Africa[286]

Created in February 2016, the African regional chapter of INGSA convenes policy practitioners and scientists from the African continent and is based in Pretoria, South Africa. The chapter is led by a steering committee, which identifies priorities, activities, and opportunities for the chapter to pursue.

INGSA Asia[287]

The Asian regional office of INGSA operates out of the Malaysian Academy of Science and exists to enable information dissemination and access in Asia. The chapter aims to serve as a support mechanism for policy-makers in the region and as a body encouraging outreach to help increase the demand for science advice from policy-makers.

INGSA Latin American and Caribbean[288]

The Latin American and Caribbean regional branch of INGSA formed a steering committee to drive the development of the Latin America and Caribbean chapter.

Foreign Ministries Science and Technology Advice Network (FMSTAN)[289]

FMSTAN is a network of science advisors working within foreign ministries. The network formed in February 2016 with a convening held by the U.S. Science and Technology Advisor at the U.S. National Academy of Sciences and involved four S&T advisors to foreign ministers from Japan, New Zealand, the United Kingdom, and the United States, as well as diplomats from other nations.

The network, whose goal is to articulate for foreign ministers the benefits of investing in S&T capacity, focuses on four areas, including raising awareness about the importance of developing an enduring S&T advisory capacity in foreign ministries; sharing best practices and lessons learned in building an S&T advisory capacity; strengthening the S&T advisory capacity in foreign ministries; and coordinating S&T diplomacy activities.

FMSTAN is a division of INGSA and often hosts meetings alongside events sponsored by another division of INGSA, the Special Interest Division on Science Diplomacy.

FutureEarth[290]

FutureEarth "mobilizes networks, sparks innovation, and turns knowledge into action" as part of its efforts to facilitate scientific research.[291] The organization focuses on understanding the interconnectedness between the earth's major systems and using this understanding to develop evidence-based strategies for sustainable development.

FutureEarth, whose aim is to strengthen the interface between science and policy, was officially announced in June 2012 at Rio +20 (the UN Conference on Sustainable Development). It is governed by the ISC, UNESCO, the Belmont Forum, and the UN Environment Programme.

Global Research Council[292]

The Global Research Council is a virtual network comprising the heads of science and engineering agencies worldwide. It aims to promote data-sharing best practices for international collaboration funding agencies.

The council's governing board consists of up to twelve representatives from national research councils, including from the Americas, the Asia-Pacific region, Europe, the Middle East and North Africa, and sub-Saharan Africa.

Global Young Academy (GYA)[293]

GYA supports activities focused on science and policy, the research environment, and science education and outreach. A cross-cutting theme of the GYA work is the UN's SDGs. GYA arose from discussions convened by the IAP in 2008 and 2009 with top young scientists and researchers from across the world at the World Economic Forum's Annual Meeting of New Champions. GYA officially launched in 2010.

Organisation for Economic Co-operation and Development (OECD)[294]

OECD is an international organization whose goal is to "shape policies that foster prosperity, equality, opportunity and wellbeing for all."[295] The OECD Global Science Forum focuses on the need for international scientific collaboration to address complex scientific challenges worldwide and supports improvements in national science policies so that the benefits of international collaboration can be more effectively shared.[296]

OECD comprises thirty-six member countries from across North and South America, Europe, and the Asia-Pacific region. Each country is represented by an ambassador on the OECD Council.

The World Academy of Sciences (TWAS)[297]

TWAS was originally founded in 1983 as the Third World Academy of Sciences by prominent scientists from the developing world. It was inaugurated officially in 1985 by the then Secretary General of the United Nations. Its main mission is to support the pursuit of scientific excellence and advance the cause of science in developing nations by "supporting sustainable prosperity through research, education, policy and diplomacy."[298] TWAS funding and personnel are administered through UNESCO. TWAS is a global merit-based academy and inducts fellows from both developing and developed countries who have made significant contributions to the advancement of science. It also supports a Young Affiliates fellows' program, which recognizes scientists with outstanding scientific achievements who are under the age of forty.

TWAS holds five regional partner offices in the developing world: in Rio de Janeiro, Brazil, at the Brazilian Academy of Sciences (Latin America and Caribbean Regional Partner); in Beijing, China, at the Chinese Academy of Sciences (East and South East Asia and the Pacific Regional Partner); in Alexandria, Egypt, at the Bibliotheca Alexandrina (Arab Regional Partner); in Bangalore, India, at the Jawaharlal Nehru Centre for Advanced Scientific Research (Central and South Asia Regional Partner); and in Pretoria, South Africa, at the Academy of Science of South Africa (Sub-Saharan Africa Regional Partner).

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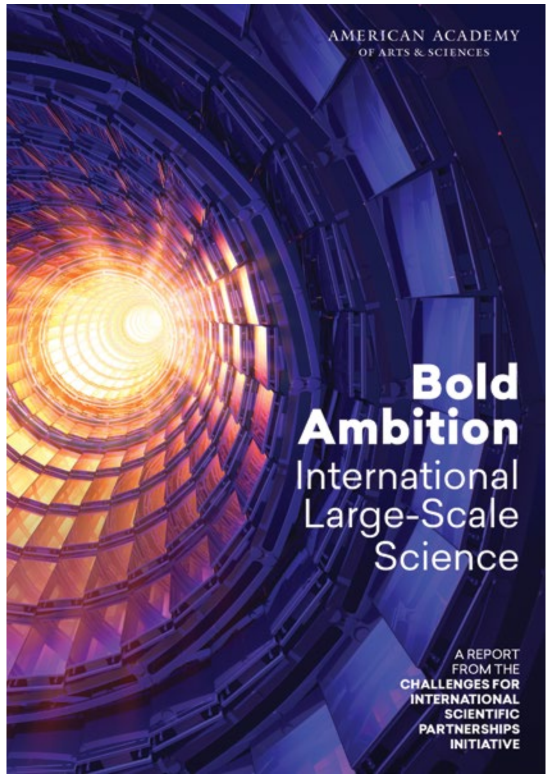

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