Trends in U.S.-China Science and Technology Cooperation: Collaborative Knowledge Production for the Twenty-First Century?

by

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EXECUTIVE SUMMARY

The governments of the United States and China have been cooperating in areas of science and technology (S&T) for 35 years under the 1979 U.S.-China Science and Technology Cooperation Agreement, which was renewed most recently in 2011. Over the years, the Agreement has facilitated a complex government-to-government relationship consisting of some 30 agency-to-agency protocols and more than 40 active sub-agreements and annexes between the technical agencies of the two countries in a wide range of fields including agriculture; energy; environmental protection; public health; earth, atmospheric, and marine sciences; basic research; standards and metrology; and nuclear safety.

Since the Agreement was first signed, varied and extensive S&T relations between the two countries have also developed outside the government-to-government relationship involving companies, universities, professional societies, nongovernmental organizations (NGOs), and various people-to-people contacts. The overall S&T relationship has thus become an exceedingly complex pattern of interactions involving S&T in support of government missions and the supply of public goods (mainly through the government-to-government channels), commercially relevant high-technology exchanges (mainly through corporate channels), and cooperation in basic research and higher education (mainly through university channels). **Measured by co-authored scientific research papers, U.S. collaboration with China now exceeds collaboration with traditional partners such as the United Kingdom, Germany, and Japan. China and the United States have become each other's main partner in scientific collaboration.**

There have been many successful and mutually beneficial cooperative activities under the Agreement over the years, and the S&T relationship has been a positive influence on U.S.-China relations in general. At the same time, as the two sides face new geopolitical uncertainties and forms of commercial competition, the context for S&T cooperation has been changing. **The manifest asymmetry in capabilities—which characterized the relationship in 1979—has been reduced as a result of the remarkable development of S&T in China, made possible by its own domestic policy initiatives and its strategic exploitation of international cooperative opportunities, especially those offered by relations with the United States. Meanwhile, demographic changes, educational failures, and U.S. budget politics have introduced uncertainties into the future of the U.S. research enterprise, the quality of which has served as a major "soft power" resource in U.S. engagement with China.**

National governments around the world continue to strengthen policies designed to enhance national capabilities for research and innovation in order to capture value from scientific and technological advances, even as they also expand international scientific cooperation. Both China and the United States exhibit these tensions between "science and technology nationalism" and "science and technology globalism"; the relationship between the two countries is an especially rich case study in how these tensions are managed. **The recognition by both sides that national research and innovation capabilities are critical assets in facing new security and economic challenges sometimes makes the identification of mutually beneficial, positive-sum programs of cooperation more difficult—though certainly not impossible, as a number of new programs of cooperation illustrate.**

For instance, as S&T issues have become more salient in the overall U.S.-China relationship, especially with regard to energy and environmental problems, we have seen new high-level initiatives coming from presidential summit meetings and from the work of the Strategic and Economic Dialogue (S&ED). Some of these initiatives draw on existing relationships developed under the Agreement, while others call for new institutional arrangements. An especially interesting and ambitious initiative is the U.S.-China Clean

Energy Research Center (CERC), which is characterized by the development of government-industry-university consortia on both sides, and by the development of innovative approaches to intellectual property issues.

More broadly, both the United States and China have a growing interest in promoting cooperation through public-private partnerships. This presages interesting new opportunities for integrating government, industry, university, and NGO capabilities, and in many cases is likely to give greater prominence to intellectual property questions. **China's policies to enhance the innovative capabilities of the country's industrial enterprises and stimulate its involvement in international S&T cooperation reinforce this trend, increasing the likelihood that the roles of both state-owned and non-state-owned enterprises in cooperative projects under the Agreement will expand. More broadly, the international expansion of Chinese companies adds a dynamic new element to bilateral S&T relations as they pursue a variety of technology acquisition strategies. These pursuits include mergers and acquisitions, contract research with foreign universities and research centers, the establishment of their own research and development (R&D) centers abroad, and, at times, surreptitious acquisitions.**

China's strong commitment to its own domestic S&T development carries implications for its S&T relations with the United States and for its approach to international scientific cooperation more generally. China has built a number of important facilities for scientific research and technological development that are attractive destinations for individual researchers, companies, and academic institutions from the United States and other countries. **China is showing a new willingness to fund an increasing share of cooperative activities with the United States, and seeks to expand its role in international scientific activities.**

These are welcome "burden sharing" initiatives, but they also point to a changing balance of influence in the bilateral relationship, and to the likelihood of enhanced Chinese influence in multilateral affairs. While China will eventually face limitations on the growth of its own spending, it is clear that the leading role the United States has enjoyed—one based on the achievements, maturity, and administrative acumen of the U.S. S&T system—is not foreordained to continue in the face of robust Chinese commitments.

This is especially true when we consider that the resources the United States brings to the relationship are increasingly constrained. U.S. budget politics leave most technical agencies with budget limitations and uncertainties, making it difficult to develop and implement cooperative programs that could enhance U.S. interests. Congressional mandates constraining the China-related activities of the Office of Science and Technology Policy (OSTP) also make the development of more robust capabilities for managing the relationship with China more difficult.

More generally, the overall health of U.S. science—especially university-based basic science—should be a matter of concern. While the United States remains a world leader in S&T, its leadership no longer remains unchallenged. Its share of the world's published papers, for instance, has declined, and the health of its research enterprise increasingly depends on foreign-born scientists and engineers, many of whom are from China. **A case can therefore be made for a more vigorous government approach to maintaining U.S. research and innovation leadership in conjunction with renewed partnerships with industry and higher education. This approach would include strong government support for maintaining basic research excellence and world-class public universities. For relations with China, it would entail the development of a more coherent, better-resourced, strategic approach to**

capturing value for U.S. interests by engaging with an increasingly capable and well-funded Chinese research and innovation system.

Over the 35 years of the Agreement, China and the United States have had somewhat different approaches and philosophies about the relationship. For the United States, cooperation with China in S&T has been more an exercise in science diplomacy, in which the abundance of S&T assets enjoyed by the United States could be used as tools in the pursuit of diplomatic objectives. For China, on the other hand, engagement with the United States has been more clearly a component of a national strategy to build scientific and technological capabilities. **As time has passed, and as Chinese capabilities have increased, there is a growing interest in using S&T for diplomatic purposes in China as well, as evidenced by the inclusion of S&T in Chinese foreign assistance programs (especially in Africa) and offers by China to host the location of international science bodies.** On the U.S. side, there is a growing realization that U.S. research and innovation enterprises can benefit from cooperative activities with China, and that engagement with China in S&T should be justified on more than political or diplomatic grounds. But, with the exception of initiatives coming from the Strategic and Economic Dialogue (S&ED), the United States has responded to this realization in a characteristically decentralized and somewhat disjointed manner. Although individual companies, universities, and selected government agencies have been active in spotting opportunities and developing strategies to exploit them, no clear overall national strategy is evident.

The presence of the sizeable Chinese professional diaspora in the United States sets China's engagement with the United States apart from its S&T relations with other countries. The flow of Chinese students and scholars into the United States and back to China has further developed the relationship between the countries and strengthened Chinese S&T over the past three and a half decades. The role of Chinese students who remained in the United States—establishing professional careers and in many cases becoming citizens—has also been important to expanding the bilateral relationship. It is a formidable task to assess the balance of benefits from these patterns of cooperation based on common ethnicity; such cooperation has helped China in its "catch-up" phase over the last 35 years and facilitated the flow of talented Chinese scientists to the United States, thus enriching the U.S. research enterprise and creating new opportunities for mutually beneficial relations.

China's overall engagement with U.S. S&T has undoubtedly played a major role in the development of Chinese wealth and power. This is especially true with regard to the exploitation of higher education opportunities at U.S. universities and the transfer of U.S. technologies as part of U.S. companies' business decisions—activities largely outside the terms of the Agreement. The government-to-government programs that are the main subject of this report have also contributed to Chinese development, but have not been conduits for the transmission of strategic information that could damage U.S. national security. In many ways, the flow of knowledge and technology to China that has occurred through various channels—governmental, industrial, academic, and ethnic—is a reflection of the relatively free, open, and decentralized nature of the U.S. approach to research and innovation. Observers around the world recognize these qualities as essential to U.S. leadership in science and technology.

For the most part, the government-to-government relationship is not a conduit for the transfer of sensitive technologies. The fact that the relationship does involve training and visits to U.S. laboratories, however, ensures that knowledge transfers occur. U.S. concerns over transfers of sensitive scientific knowledge or technology have led technical agencies to put in place mechanisms to vet visiting scientists and engineers. Overall, though, the government-to-government relationship is much less a conduit for technology transfer than commercial relations or academic channels.

In sum, the U.S.-China S&T relationship has become a complex, multifaceted pattern of engagement, particularly as China brings new capabilities, new wealth, and a strong sense of strategy to its S&T interactions with United States. These twenty-first-century realities offer new challenges and opportunities for the United States, and warrant both a reconsideration of U.S. goals for the relationship and an assessment of the policy and organizational resources available for meeting those goals.

INTRODUCTION

January 31, 2009, marked the thirtieth anniversary of the signing of the Agreement between the Governments of the People's Republic of China and the United States of America on Cooperation in Science and Technology (hereafter the Agreement). On January 19, 2011, China and the United States renewed the Agreement for another five years. The Agreement has led to a complex government-to-government relationship characterized by a large number of protocols and memoranda of understanding (MOU) between both countries' technical agencies in a wide range of fields including agriculture; energy; environmental protection; public health; earth, atmospheric, and marine sciences; basic research; standards and metrology; and S&T in support of regulatory policy.

Few would have imagined in 1979 what the Agreement would bring. The web of S&T relationships is now characterized by multiple institutional strands, with multiple stakeholders having multiple objectives. Through its reforms and investments in research institutes and universities, and its exploitation of training, research, and technology transfer opportunities in the international environment, China has made great progress in promoting its S&T and has become an attractive partner in research and innovation for many constituencies in the United States and in other countries. Since 1979, the manifest asymmetry in capabilities has been reduced.[1]

In a number of research areas, and for a number of pressing global problems, the S&T partnership between the United States and China will play a critical role in determining how the twenty-first-century unfolds.[2] Revolutions in science-based technologies hold the potential to significantly enhance national wealth and power in both countries, while shared interests in the management of collective "goods" and "bads"—pollution, water and energy availability, public health, food supplies, and a broad range of issues involving risk and safety—focus increased attention on knowledge-based approaches to these challenges. The Agreement has built institutional foundations for cooperation in basic science, commercial technologies, and the S&T needed to address the challenges of providing public goods.

Over the course of 30-plus years there have been a number of changes in the context of the S&T relationship. First, there have been profound changes in the geopolitical realities. Sino-American rapprochement in the 1970s, including the initiation of S&T relations, was driven largely by shared concerns about Soviet power and its use. Out of these concerns, the normalization of Sino-American relations under a Democratic president was followed by a Republican administration that sought to build

[1] Whereas in 1978 there were three U.S.-China jointly authored papers, in 2012 there were 20,371. Caroline S. Wagner, Lutz Bornmann, and Loet Leydesdorff, "Recent Developments in China-U.S. Cooperation in Science," (forthcoming). *http://arxiv.org/abs/1404.6545*.

[2] Measured by co-authored papers, U.S. collaboration with China now exceeds that of such traditional partners as the United Kingdom, Germany, and Japan. China and the United States have become each other's main partner in collaboration. Caroline S. Wagner, Lutz Bornmann, and Loet Leydesdorff, "Recent Developments in China-U.S. Cooperation in Science," (forthcoming). *http://arxiv.org/abs/1404.6545*.

upon the foundation for S&T cooperation by expanding the relationship, including—importantly—through the relaxation of export control policies.[3]

The fall of the Soviet Union and the suppression of the demonstrations in Tiananmen Square changed the geopolitical realities in fundamental ways, leading to a temporary suspension of the relationship and—over the longer term—the growth of mistrust and new tensions. These tensions are illustrated by the findings of the Select Committee on U.S. National Security and Military/Commercial Concerns with the People's Republic of China (the Cox Committee) concerning the leakage of strategic technologies, conflicts over trade and investment issues, growing concerns over intellectual property rights (IPR) violations and Chinese espionage, and worries over Chinese military spending and technology acquisitions.[4] Yet in spite of these changing geopolitical realities, the S&T relationship continued to expand with the reactivation and further development of the government-to-government programs in the early 1990s, a rapid increase in foreign direct investment (FDI)-related technology transfers at about the same time, and the continuing increase in Chinese students coming to U.S. universities to pursue graduate education in science and engineering.

Meanwhile, China’s post-Mao leaders were set on building sustainable S&T capabilities in ways that had eluded China during a century of foreign incursions, civil war, and political radicalism. China’s systems for research and innovation in the late 1970s were close to broken. The Cultural Revolution had interrupted most areas of research and higher education, and China’s socialist planned economy showed few signs of innovative potential. S&T, like the economy as a whole, had to be reformed and opened up. Thus began the fascinating story of the growth of Chinese S&T capabilities over the past 35 years through a combination of domestic reforms and policy initiatives, and international collaboration and assistance. In retrospect, the story is especially remarkable because of the ways in which human, material, and ideational resources from the international environment have been linked to domestic reform efforts such that the growth of Chinese S&T capabilities was kept in rough synchronization with an increasingly globalized system of research and innovation. The relationship with the United States was central to this process.

Were it not for domestic reforms and policy initiatives, resources from the United States—and from the international environment more generally—would not have been as influential. Such reforms and initiatives include, most recently, the initiation of China’s Medium- to Long-Term Plan 2006-2020, which is currently undergoing an extensive mid-point review. While these efforts have certainly not been without problems, and are in many ways incomplete, they can also be credited for turning what were largely moribund systems of research and innovation in the late 1970s into the dynamic environment of today, which attracts increasing international attention. By a number of measures—manpower and

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[3] Jin Xiaoming, “The China-U.S. Relationship in Science and Technology” (Conference on China's Emerging Technological Trajectory in the 21st Century, Rensselaer Polytechnic Institute, September 4-6, 2003). *http://china-us.uoregon.edu/papers.php*; Richard P. Suttmeier, “U.S.-China Scientific Cooperation: An Assessment of the First Two Years (1980-1981),” Report to the Department of State, 1982. *http://china-us.uoregon.edu/papers.php*.

[4] The Cox Committee was created on June 18, 1998, and given the responsibility to investigate reports of illicit transfers of strategic technologies used to enhance Chinese nuclear weapons and missile capabilities. The Committee’s report was released in redacted form in May 1999, and alleged that serious transfers had occurred. The unclassified report is available at *http://www.house.gov/coxreport/*. The report’s findings were rejected by the Chinese and the unclassified version was subjected to a number of expert critiques on the U.S. side. See, for instance, M.M. May, ed., *The Cox Committee Report: An Assessment* (Stanford University, Center for International Security and Cooperation, December 1999). *http://iis-db.stanford.edu/pubs/10331/cox.pdf*.

expenditure indicators, outputs of publications and patents, and the successful completion of important research facilities and engineering projects—China has now become an increasingly important player in world science and engineering.[5] The researchers and institutions of China are, in short, increasingly attractive as partners in research and technological development; as a result, we now see types of interdependencies that would have been inconceivable 30 years ago.

Changes in science and technology, themselves, have also altered the context of the relationship. These changes apply to intellectual content or substance, to methodologies, and to the social relations of S&T. When the Agreement was signed in 1979, the revolutions in computer science and information technology were only beginning. Molecular biology and biotechnology were also relatively immature, as was modern materials science. Nanotechnology was largely a conceptual enterprise. Since then, of course, there has been remarkable progress in all these fields, and with it the creation of new science-based industries. China, for the most part, was not a player in any of these fields at that time, but has now become highly active and productive, believing that its future wealth and power depend largely on the successful promotion of science-based industries. The revolution in instrumentation through the application of information and communications technology (ICT)—which was beginning 30-plus years ago, and about which China knew little—transformed the research environment and now reinforces trends toward interdisciplinarity.

At the time the Agreement was signed, personal computing was only just beginning and there was no Internet. University-industry relations were nowhere near the intensity they are today, and intellectual property claims to new knowledge tended to be peripheral for academic researchers. Defense technologies and civilian technologies tended to be developed in separate realms, with the result that management of dual-use technologies was not as central a national security issue as it has become. While science had always been characterized by international collaborations, the costs of international transportation and communications imposed limits on the extent of collaborations one might expect. With the drastic reduction of transportation and communication costs as a result of new technologies, opportunities for international collaboration began to increase significantly. Relatedly, as a result of both reduced transport and communication costs and the spread of national policies to promote S&T, research and innovation capabilities began to spread to new parts of the world, especially to Asia. The widespread diffusion of digital technology, combined with growing numbers of technically trained individuals around the world, facilitated the formation of global production networks—and more recently, global innovation networks—in which China plays an increasingly important role.

In short, over the past 30-plus years, important new areas of science—supporting important new industries—have opened up, IPR issues are never far from the minds of researchers, and dual-use technologies complicate the reconciliation of trade and defense considerations in the making of national security policy. There has been an expansion in the number of centers of research and innovation around the world, and international collaborations have increased. Research and innovation increasingly require diverse competencies, which—due to modern communications—can be drawn from around the world.

In this context, the United States remains a world leader in S&T, but its leadership no longer remains unchallenged. Its share of the world's published papers, for instance, has declined, and the health of its

[5] Chinese R&D expenditures and the number of professional papers published by Chinese researchers are now second in the world after the United States. See National Science Board, "Science and Engineering Indicators 2014," *http://www.nsf.gov/statistics/seind14/*. See also Battelle and *R&D Magazine*, "2014 Global R&D Funding Forecast," December 2013.

research enterprise depends increasingly on foreign-born scientists and engineers, many of whom are from China.[6] Indeed, the growth of a large technical community of Chinese-born scientists and engineers in the United States over the course of the past 35 years shapes the ways the S&T relationship has evolved. Most of these professionals came to the United States for graduate study and, following receipt of their degrees, decided to make their careers in U.S. universities, companies, and government agencies. Over time, these professionals have played a critical bridge role for enhancing cooperation between the two sides as participants in joint research collaborations and facilitators of commercial technology flows. As products of a strong U.S. university system and 35 years of open educational exchanges, they give the U.S.-China S&T relationship a distinctive quality not seen in China's relations with other countries with smaller professional diasporic communities.

The rise of a series of global problems—issues that have substantial technical content and in which China and the United States have particular interests and responsibilities—also illustrates the changing context of the relationship. These problems include climate change, environmental protection, energy and water quality and availability, and epidemics and infectious diseases. They also include terrorism, proliferation of weapons of mass destruction, information security and other national security-related issues, and issues pertaining to the operation of the global economy such as the nature of international regimes for technical standards and intellectual property. These challenges either didn't exist in 1979, or have become considerably more pressing since then. China and the United States are both very sensitive to the ways in which these problems affect them, and—as the world's two leading consumers of energy and producers of greenhouse gases—they have special responsibilities for solving, or at least ameliorating, these problems. At the same time, they provide opportunities for—some might argue, they demand— intensified bilateral cooperation and coordinated leadership in multilateral settings since the ways in which the two countries approach these issues have global implications.

But while the stakes are rising, questions about the modalities of relationships in S&T are also becoming more complex. Research and innovation today are frequently characterized by the shortened time between scientific discovery and technological application. Scientific research is therefore seldom far from commercial application and from the emergence of dual-use technologies having both commercial and military applications. Concerns among business enterprises, universities, and governments for protecting proprietary knowledge, or knowledge of relevance to national security, have been heightened. Thus, the win-win, positive-sum assumptions about cooperation in science have become complicated by the fact that the development of commercial and national security applications of new knowledge often introduce competitive pressures and the possibility of zero-sum outcomes. National governments continue to adopt policies designed to capture value from scientific and technological advances and enhance national capabilities for research and innovation, even as they expand international cooperation. Both China and the United States exhibit these tensions between "science and technology nationalism" and "science and technology globalism"; the relationship between the countries is an especially rich case of how these tensions are managed.

Finally, the latest turns of Chinese S&T policy development create new opportunities and challenges for the bilateral relationship. China has realized that it is at a stage of development where far more attention must be given to basic science and to building a culture of basic research. At the same time, as it tries to develop its national innovation system, China realizes that its industrial enterprises must become far more innovative if the goal of an "enterprise-centered innovation system" is to be realized. The severity of

[6] PhD recipients from China make up the largest group (23 percent) of foreign doctoral degree recipients residing in the United States. National Science Board, "Science and Engineering Indicators 2014," *http://www.nsf.gov/statistics/seind14/*.

Chinese environmental, industrial, and food safety problems also calls attention to the important role that S&T can play in generating relevant innovations, while helping to establish a modern regulatory framework for controlling "public bads." All this is taking place in the context of ambitious policies to promote "strategic emerging industries," which are stimulating both domestic efforts at innovation and vigorous efforts to acquire technology from abroad using a variety of means. The Agreement and the broader S&T relationship that has developed over the past 35 years provide frameworks for the enhancement of mutually beneficial bilateral cooperation in these areas. The realization of these benefits, however, requires a refocusing on the relationship on both sides, and attention to a series of problems (explored below) that keep the relationship from reaching its full potential.

U.S.-CHINA BILATERAL GOVERNMENT S&T PROGRAMS

As suggested above, the U.S.-China S&T relationship can now be thought of as a complex web of interactions involving not only the government agencies of the two countries, but also extensive commercial interactions and academic relationships. The focus here is more on the former, but the latter two are highly significant and warrant discussion, as indicated further below.

The government-to-government relationship conducted under the Agreement now consists of some 30 subordinate agency-to-agency protocols (themselves having more than 40 active sub-agreements and annexes), and covers a broad range of activities from basic research to technical assistance in domains ranging from agriculture to transportation. The implementation of the Agreement is the responsibility of the Joint Commission on S&T Cooperation (JCM), which meets every two years (the most recent meeting took place in May 2012; the next meeting is scheduled for September 11-12, 2014). The JCM is co-chaired by the Chinese Minister of Science and Technology and by the U.S. President's Science Advisor, and includes senior officials from the technical agencies of the two sides. The S&T Executive Secretaries Meeting (ESM), led by the Office of Science and Technology Cooperation of the Department of State and by the International Cooperation Bureau of the Chinese Ministry of Science and Technology, meets during the years when the JCM does not meet (the most recent meeting took place in October 2013). Activities under the Agreement include many agency-to-agency ties based on protocols that date back to the late 1970s. In some cases, the relationships have waxed and waned, but in others, after many years of interactions, the relationships have deepened and broadened.

While most of the government-to-government programs are conducted under the S&T Agreement, several new initiatives fall outside of the Agreement and point to growing complexity in the established governance mechanisms for S&T cooperation. For instance, over the past 10 years there has been growth in activities with significant S&T components under government-to-government agreements, which—in some ways—supersede the S&T Agreement. This is particularly true with regard to initiatives growing out of the Strategic Economic Dialogue (SED), which began in 2006, and its successor, the Strategic and Economic Dialogue (S&ED).[7]

The SED, for instance, initiated the Ten-Year Framework on Energy and Environment Cooperation (TYF) in 2008, which identified clean water, clean air, clean and efficient transportation, clean and efficient electricity, nature reserves/protected areas, wetlands protection, and energy efficiency as areas

[7] In reviewing activities under the "strategic track" of the S&ED, the Department of State notes some 91 items of cooperation, some of which fall under the Agreement while others do not, but—nevertheless—have scientific and technological components. This includes a number of issues having to do with national security as well. See U.S. Department of State, "U.S.-China Strategic and Economic Dialogue Outcomes of the Strategic Track." *http://www.state.gov/r/pa/prs/ps/2013/07/211861.htm*.

for cooperation. In agreeing to the TYF, the two sides in effect agreed to give greater attention and priority to a variety of activities already provided for by various protocols and MOUs under the Agreement. At the same time, the TYF also added new approaches to cooperation, including the initiation of the EcoPartnership program intended to facilitate new forms of public-private and people-to-people relations. While these relations have not always involved S&T directly, a number of them have. For instance, in 2013 six new EcoPartnerships were announced, including one involving Coca-Cola and a Chinese environmental technology firm working on environmentally friendly plastic bottles, another on groundwater management involving a consortium led by the New York Institute of Technology and Peking University, and another involving Stony Brook University and Tongji University on landfill-gas-to-liquids technologies.[8]

Similarly, in response to the April 2013 U.S.-China Joint Statement on Climate Change issued during Secretary of State John Kerry's visit to Beijing, the S&ED now includes a joint Climate Change Working Group chaired by the Department of State and China's National Development and Reform Commission. The Climate Change Working Group has identified five important areas for cooperation: emission reductions from heavy-duty and other vehicles; smart grids; carbon capture, utilization, and storage; collecting and managing greenhouse gas emissions data; and energy efficiency in buildings and industry. Again, these initiatives build on established programs under the Agreement, but also involve the participation of other agencies such as the U.S. Department of Transportation and the Ministry of Industry and Information Technology of China.[9]

In keeping with the evolution of the relationship, government-to-government ties now occur at several different levels. Long-standing relationships between the technical agencies of the two governments have produced many activities at the working level, governed by protocols and MOUs, and typically implemented by bilateral joint working groups that attempt to meet annually. The JCM and ESM mechanisms, which go back to the beginning of the relationship, constitute a second level. But the growing prominence of S&T issues, especially with regard to energy and the environment, has led to the inclusion of these subjects in high-level political engagements (as represented by the S&ED) and, in recent years, presidential-level summits. The focus of this report, however, is on the major areas of cooperation under the Agreement.

The following agencies have been especially active.

The U.S. Department of Agriculture (USDA)

USDA's long-standing relationship with China now involves a number of USDA offices, including the Agricultural Research Service (ARS), the Animal and Plant Health Inspection Service, the Foreign Agricultural Service, the National Institute of Food and Agriculture (NIFA), and the U.S. Forest Service. Partners on the Chinese side have included the Ministry of Agriculture, the Ministry of Science and Technology (MOST), the Ministry of Water Resources, and—under an MOU renewed in 2011—the State Forestry Administration.[10] The various activities that have occurred under these agreements have

[8] U.S. Department of State, *U.S.-China EcoPartnerships Program*, July 10, 2013. *http://www.state.gov/r/pa/prs/ps/2013/07/211792.htm*.

[9] U.S. Department of State, *Report of the U.S.-China Climate Change Working Group to the Strategic and Economic Dialogue*, July 10, 2013. *http://www.state.gov/e/oes/rls/pr/2013/211842.htm*.

[10] In 2013, for instance, the U.S. Forest Service worked with its Chinese counterparts to conduct an assessment of 11 forest health pilot projects. U.S. Department of State, "Implementation of Agreement between the United States and China on Science and Technology," in *2014 Biennial Report to the United States Congress*, n.d.

involved scientific research, food safety questions, and regulatory and bio-safety issues associated with agricultural biotechnology.

Other agriculture-related activities have included cooperation on ethanol and biofuels development, forestry management, soil and water conservation, plant and animal health, control of invasive species, agricultural economics and statistics, nutrition issues, and cooperation on research and management of individual plant and animal species. These activities have involved a number of other Chinese entities, including the Administration of Quality Supervision and Inspection and Quarantine, the Ministry of Commerce, the Ministry of Public Health, the Shanghai Academy of Agricultural Sciences, the Chinese Academy of Agricultural Sciences, the China Center for Disease Prevention and Control, the Chinese Academy of Sciences (CAS), Fudan University, the National Development and Reform Commission (NDRC), and various provincial departments of agriculture. USDA has also cooperated with the Chinese Academy of Agricultural Sciences in the establishment and operation of a Sino-U.S. Biological Control Lab in Beijing.[11]

In 2009, USDA and the Ministry of Agriculture renewed the Memorandum of Understanding Concerning Cooperation in Agriculture and Related Fields. The relationship was further upgraded in 2012, when USDA signed a new Plan for Strategic Cooperation with the Ministry of Agriculture. The Plan calls for cooperation in the areas of food safety, food security, and sustainable agriculture, and promotes efforts to enhance business relationships between the agricultural industries of the two countries.[12]

Cooperation in scientific research deepened in 2002 with the signing of the Protocol on Cooperation in Agricultural Science and Technology with MOST. The Protocol involves ARS on the U.S. side and various research entities on the Chinese side. Activities under the Protocol are spelled out in twelve annexes:

Annex I: Grazing land ecosystem restoration cooperative activities
Annex II: Soil and water conservation and environmental protection cooperative activities
Annex III: Wheat quality and pathology cooperative activities (includes general biotechnology)
Annex IV: Facilitating plant genetic resource exchange cooperative activities
Annex V: Agricultural products processing cooperative activities
Annex VI: Food safety and quality cooperative activities (animal products)
Annex VII: Biofuel cooperative activities
Annex VIII: Food safety
Annex IX: Dairy production and dairy processing cooperative activities
Annex X: Collaboration on efficient irrigation
Annex XI: USDA-MOST collaboration to establish centers for agro-ecology and sustainability
Annex XII: Establish Sino-U.S. centers for water use for arid agriculture

[11] The laboratory, one of several overseas biological control laboratories maintained by USDA, does research on the natural biological enemies of weeds, pests, and plant diseases affecting agriculture in the United States and China. U.S. Department of Agriculture, Agricultural Research Service, "Sino-American Biological Control Laboratory, Sino-ABCL Agreement (2009-2014)." *http://www.ars.usda.gov/research/docs.htm?docid=18856&page=4*.
[12] U.S. Department of Agriculture, "U.S., China Sign Plan of Strategic Cooperation in Agriculture," *http://www.usda.gov/wps/portal/usda/usdahome?contentid=2012/02/0057.xml*.

Although some fieldwork is conducted by U.S. researchers in China, much of the activity under the Protocol has involved postdoctoral fellows from China visiting ARS labs. Well over 400 joint publications have resulted from work under this agreement.[13]

On the occasion of the renewal of the Protocol in 2012, the China and the United States agreed to give more focused priority to three areas of cooperation of particular importance to the two countries. This led to the signing that year of a new Protocol on Flagship Projects, which identifies work in the following fields as initial priority areas: agricultural biotechnology, water-saving technologies, and technologies for the collection and management of genetic materials. The Protocol provides for a management structure involving a joint steering committee to meet annually, and a joint advisory panel (three distinguished business and academic leaders from each side) that would also meet annually.[14]

To date, work in the water-saving technology area has included exchanges dealing with watershed research and tools to support land management decision making, water use in relation to crop productivity, and sensors development and applications. In the area of biotechnology, the foci have included maize and wheat research, including efforts to promote globally open genome sequence data for the maize research community, globally open data for agriculture and nutrition, and research on genotype analysis and genetic resources for key crops. The gene bank technology program focuses on germplasm enhancement of maize, and involves public-private partnerships with the seed industry.[15]

In addition to the intramural work conducted in ARS facilities, the U.S. National Institute of Food and Agriculture (which supports extramural research, typically in universities, outside of USDA laboratories) has supported research and education projects in universities that have involved collaboration with China.[16]

The Department of Energy (DOE)

DOE has been engaged with China in the area of high-energy physics since 1979, but its involvement has broadened considerably in the face of global energy and climate change questions. As China pushes ahead with measures intended to ameliorate the environmental effects of burning coal, and as the United States struggles to develop a sound strategy for its own reliance on coal, opportunities for cooperation in clean coal technologies are especially notable. China requires that new coal-burning plants be equipped with new technologies that increase efficiencies and reduce emissions, and has redoubled its efforts to develop

[13] Interview, U.S. Department of Agriculture, February 24, 2014.
[14] U.S. Department of Agriculture, Agricultural Research Service, "Protocol between USDA and China's MOST for Cooperation on U.S.-China Agricultural Flagship Projects." *http://www.ars.usda.gov/research/projects/projects.htm?ACCN_NO=422525*.
[15] Marcella Witting, "ARS-China Cooperation in Agricultural Science and Technology" (Remarks presented at the U.S.-China Executive Secretaries Meeting, October 31, 2013). USDA, the National Science Foundation (NSF), and the National Corn Growers Association provide financial support for the Maize Genetics and Genomics Database (Maize GDB), a website intended to serve the global community of maize researchers. See *http://www.maizegdb.org/*. To enhance cooperation in this area, a Chinese language version of the site will be introduced in 2014.
[16] China-related grants have been made to Colorado State University, East Carolina University, Mississippi State University, South Dakota State University, Southern University, the University of Nevada, Auburn University, the University of Missouri, Rutgers University, Purdue University, the University of California, the University of South Carolina, Utah State University, George Mason University, the University of Florida, Iowa State University, Alabama A&M University, Clemson University, the University of Florida, and Michigan State University. Interview, U.S. Department of Agriculture, February 21, 2014.

commercial-scale facilities for coal gasification and liquefaction, and for CO2 capture and storage. With China's increasing wealth, the large demonstration facilities it is building are of considerable interest to the United States.[17]

In 2008 the two sides agreed to a Ten-Year Framework for Cooperation on Energy and the Environment, which includes action plans for cooperative activity in energy efficiency, electricity, and transportation, as well as other topics pertaining to environmental quality. The November 2009 summit meeting between U.S. President Barack Obama and then Chinese President Hu Jintao led to the announcement of a series of initiatives constituting a bilateral clean energy agenda. These initiatives include the U.S.-China Clean Energy Research Center (CERC), discussed further below, an electric vehicle initiative, an energy efficiency action plan, a renewable energy partnership, cooperation on twenty-first-century coal, a shale gas resource initiative, and the U.S.-China Energy Cooperation Program to facilitate the involvement of U.S. companies in the Chinese energy market. Many build on existing agreements under the overall S&T Agreement, but the high-level political endorsement of these programs has led to a new level of activism for public-private programs involving universities and industry, as well as DOE national laboratories.[18]

A number of formal agreements between DOE and Chinese entities provide a framework for what is becoming very extensive cooperation. A Protocol for Cooperation in the Field of Fossil Energy Technology Development and Utilization between DOE and MOST, originally signed in 2000, includes six annexes for cooperation in the following:

Annex I: Power Systems (with China Power Investment Corporation)
Annex II: Clean Fuels (with the NDRC]
Annex III: Oil and Gas (with China Petroleum and Chemical Industries Association)
Annex IV: Energy and Environmental Control Technologies (with MOST)
Annex V: Climate Science (with CAS and the China Meteorological Administration)
Annex VI: Advanced Coal-Based Energy Systems (with CAS)

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[17] MOST, along with the Huaneng Group, one of China's largest state-owned electric power companies, had set aside funds for participation in the DOE-sponsored FutureGen, a project for the construction of a zero-emissions, coal-fired demonstration plant that employs carbon capture and storage technologies to produce electricity and hydrogen. The project was shelved in 2008 due to concerns about rising costs. With the revival of the FutureGen Alliance, reportedly there is again a Chinese commitment, funded this time by Shenhua Group Corporation, a state-owned energy and mining company. ExchangeMonitor Publications & Forums, "Chinese Research Group Joins FutureGen Alliance." *http://ghgnews.com/index.cfm/chinese-research-group-joins-futuregen-alliance/*.

[18] Apart from CERC, discussed further below, cooperative activities involving DOE laboratories have become numerous and diverse. Under the Electric Vehicle Initiative, for instance, the Argonne National Laboratory plays a key role. The Energy Efficiency Action Plan involves Lawrence Berkeley National Laboratory and Oak Ridge National Laboratory. Ames National Laboratory maintains cooperative research activities with several Chinese laboratories in the area of magnetic materials of relevance to improved efficiency. The National Renewable Energy Laboratory plays a key role in the Renewable Energy Partnership, as do the Pacific Northwest National Laboratory and Los Alamos National Laboratory in the science and technology of biofuels. The National Energy Technology Laboratory and the Pacific Northwest National Laboratory are engaged with CAS on various clean coal initiatives, as is Lawrence Livermore National Laboratory. The Chinese entities partnering in these various activities include CAS, universities, and Chinese companies. See U.S. Department of Energy, *U.S.-China Clean Energy Cooperation, A Progress Report by the U.S. Department of Energy*, January 2011. *http://energy.gov/sites/prod/files/piprod/documents/USChinaCleanEnergy.PDF*. In 2009, the Pacific Northwest National Laboratory and the National Energy Technology Laboratory joined the Chinese Academy of Sciences institutes for a new program in advanced coal-based energy systems as part of Annex VI to the U.S.-China Fossil Energy Protocol. Pacific Northwest National Laboratory, "PNNL, Chinese Researchers Begin Cooperative Clean Energy Work." *http://www.pnnl.gov/science/highlights/highlight.asp?id=797*.

Activities under these annexes involve training, R&D and demonstrations, and capacity building in areas of high global salience, and are becoming increasingly central to Sino-U.S. relations as a result of the S&ED as well as the Ten-Year Framework for Energy and Environment Cooperation.[19]

With the increasing attention being given to energy efficiency in China and to renewable energy technologies, programs for technology sharing, technical assistance, training, and business development help link the two countries in highly important areas of technology and policy. A variety of activities in the energy efficiency area are conducted under the multi-agency Energy Efficiency Action Plan, co-chaired on the U.S. side by DOE and the U.S. Environmental Protection Agency (EPA) and by the NDRC on the Chinese side.[20] The two sides also maintain a U.S.-China Renewable Energy Partnership, a public-private effort led by DOE's National Renewable Energy Laboratory and the Chinese National Energy Administration, with a variety of initiatives in the areas of wind energy, solar, biofuels, grid integration, standards and testing, and policy and planning.[21]

DOE has a number of ties with CAS in areas of basic research, beginning with agreements for cooperation in high-energy physics and nuclear fusion. As noted, the high-energy physics agreement was first signed in January 1979, and has provided for close cooperation between high-energy physics communities in the two countries, especially in support of the establishment of and recent upgrade to the Beijing Electron Positron Collider, an important facility that allows for world-class research in China. DOE has also assisted in the design and construction of other major facilities, including the new Shanghai Synchrotron Radiation Facility.[22] The largest current collaboration under this agreement is the neutrino oscillation research facility at the site of the Daya Bay nuclear power plant complex. Neutrinos, subatomic particles which are normally difficult to detect, are produced in abundance at several nuclear power plants at the site, thus making possible sophisticated measurements of neutrino behavior. The United States has contributed detectors for the facility, while China has paid for the construction and civil engineering. Research at the facility has involved collaboration among more than 200 scientists from several countries, with leadership on the U.S. side coming from the Lawrence Berkeley and Brookhaven National Laboratories. In January 2014, China began preparations for a $300 million facility at Daya Bay

[19] For example, under the Clean Fuels Annex (II), the two sides have cooperated in the development of direct coal liquefaction technologies. With DOE support, the University of West Virginia has worked with Shenhua Group Corporation on economic and environmental assessments for the latter's plans to construct a DCL demonstration plant. This led to further studies in support of capturing and storing CO2 resulting from the operation of the plant; these studies have resulted in a successful demonstration of a carbon capture and storage facility in China. Activities under the Clean Fuels Annex (II) have also included a series of workshops providing for the interaction of representatives of companies, government agencies, and universities from the two sides. See U.S.-China Economic and Security Review Commission, *Hearing on U.S.-China Clean Energy Cooperation: Status, Challenges, and Opportunities*, Testimony of Jerald J. Fletcher, April 25, 2014.

[20] See U.S. Department of State, "Energy Efficiency Action Plan." *http://www.state.gov/e/oes/eqt/tenyearframework/141875.htm*.

[21] ChinaFAQs.org, "ChinaFAQs: U.S.-China Renewable Energy Partnership." *http://www.chinafaqs.org/library/chinafaqs-us-china-renewable-energy-partnership*.

[22] The Shanghai Synchrotron is China's largest and most expensive research platform or "big science" facility. David Cyranoski, "China Joins World-Class Synchrotron Club," *Nature* 459 (May 6, 2009): 16-17. *http://www.nature.com/news/2009/090506/full/459016a.html*. As a "third-generation" light source, it is comparable to facilities in Japan, France, and the United States. Since the signing of the Agreement, the U.S. physics community has been supportive of China's efforts to build facilities that would allow the Chinese physics community to participate in the international effort to advance fundamental research in the belief that "the better the facilities, the better the field." In building these large, expensive facilities, the international physics community has an interest in seeing that unnecessary duplications are avoided and that new facilities offer distinctive new features.

to house a powerful new neutrino detector.[23] There have been a number of important achievements stemming from this project pertaining to the nature of matter and understandings of the origins of the universe.[24]

The Protocol on Cooperation in the Fields of Nuclear Physics and Controlled Magnetic Fusion Research was originally signed in 1983. Activities under this Protocol have focused mainly on training, cooperative research, and design assistance to China in the construction of its new Experimental Advanced Superconducting Tokamak facility at the Institute of Plasma Physics of the Chinese Academy of Sciences in Hefei. This facility, which was tested and began operation in September 2006, is now recognized as one of the leading fusion research centers in the world. With China joining the International Thermonuclear Experimental Reactor (ITER) project, opportunities for bilateral cooperation on multilateral issues have also increased.[25] In 2012, the two sides signed a new cooperative agreement to establish a Collaborative Innovation Center for Advanced Fusion Energy and Plasma Science. In both the high-energy physics and nuclear fusion cases, one can again see that China's increasing ability and willingness to pay for large, complex, and expensive facilities is among the reasons why it has become an increasingly attractive partner for international cooperation.

Cooperation with CAS has broadened and deepened in recent years. In January 2011, a new Protocol for Cooperation in Energy Sciences was signed; the Protocol includes all the main areas in the portfolio of the DOE Office of Science: high-energy physics, nuclear physics, fusion energy sciences, basic energy sciences, and biological environmental research. This agreement, which builds on the earlier high-energy physics and fusion agreements, established a joint coordinating committee that held its first meeting in April 2012 and its second meeting in May 2013. The joint coordinating committee is now in the process of exploring the establishment of various annexes to the agreement for specific projects.[26]

In December 2011, DOE and CAS signed an MOU on Cooperation in Nuclear Energy Science and Technology, which involves the DOE Office of Nuclear Energy and is subsumed under the Agreement for the Peaceful Uses of Nuclear Energy. The MOU provides for cooperation between Oak Ridge National Laboratory, the Idaho National Laboratory, and the CAS Institute for Applied Physics in Shanghai in the areas of molten salt coolant technology and uranium resources from sea water (with Oak Ridge) and the use of nuclear power as a heat source in hybrid energy systems (with Idaho). With significant reserves of thorium, China sees thorium molten salt technology as a promising fourth-generation nuclear power source, and will soon begin construction of a 10 MW demonstration plant.[27] Oak Ridge had been a leader in this field, but the technology has not enjoyed priority attention in recent years. A planning meeting to implement the terms of the MOU was cancelled due to the 2013 shutdown of the U.S. government, but was later held in early May 2014. The two sides are expected to announce an agreement for a cooperative

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[23] Jane Qiu, "China Builds Mammoth Detector to Probe Mysteries of Neutrino Mass," *Science* 343 (February 7, 2014). *http://www.sciencemag.org/content/343/6171/590.full*.
[24] Lawrence Berkeley National Laboratory, "New Results from Daya Bay," August 21, 2013. *http://www.sciencenewsline.com/summary/2013082121150004.html*.
[25] Dennis Normile, "Waiting for ITER, Fusion Jocks Look EAST," *Science* 312 (19 May, 2006): 992-93.
[26] Sun Hui, "CAS-DOE Collaboration in Basic Sciences," (Remarks presented at the U.S.-China Executive Secretaries Meeting, October 31, 2013).
[27] cf., Steven Chen, "Chinese Scientists Urged to Develop New Thorium Nuclear Reactors by 2024," *South China Morning Post*, March 19, 2014. *http://www.scmp.com/news/china/article/1452011/chinese-scientists-urged-develop-new-thorium-nuclear-reactors-2024*.

research and development agreement in the near future, under which China will pay for R&D and technical information on thorium reactors supplied by the United States.[28]

In these various energy-related initiatives in basic science, the U.S. side is not only gaining research access to a variety of important facilities established in China and expanding opportunities for technical exchanges with some of China's leading scientists, but is also seeing the Chinese side offering to finance a generous portion of some of these activities.

One of the most notable of the new energy initiatives is the Clean Energy Research Center (CERC), established by a protocol signed in November 2009 by Presidents Obama and Hu. CERC involves the establishment of government-industry-university consortia in the two countries in three areas: advanced coal technology, building energy efficiency, and clean vehicle technology. CERC is seen by some on both sides as a new model for international cooperation; officials at MOST, for instance, expressed the view that they would like to replicate the CERC model in relations with other countries, and with the United States in other areas such as the health sciences.[29]

The coal technology consortium is led by West Virginia University on the U.S. side, with 10 additional U.S. partners. Huazhong University of Science and Technology has the lead on the Chinese side with 16 partners. Lawrence Berkeley National Laboratory leads the building efficiency group on the U.S. side with 15 partners, while the Ministry of Housing and Urban and Rural Development leads the Chinese consortium of 37 members. The University of Michigan and Tsinghua University are the leaders of the clean vehicle program, with 15 partners on the U.S. side and 19 on the Chinese side (see the Appendix for a listing of participating organizations).[30]

The establishment of the consortia, which involved industry participation, put a premium on clarifying intellectual property (IP) considerations; as a result, considerable effort was given to the development of common IP understandings on the two sides.[31] These understandings are reflected in an IP rights (IPR) annex to the CERC Protocol, which builds on and extends Annex 1 of the S&T Agreement (the IPR annex added to the Agreement in 1991). These common IP understandings have also been incorporated into the technology management plans negotiated to guide the work of the consortia. In addition, CERC is preparing an IP handbook that explains relevant U.S. and Chinese IP laws for use by CERC researchers who are typically not trained in law. The program maintains a web portal (*Ipknowledge.org*) for use by participants, and has conducted two bilateral workshops, the results of which are online. DOE and MOST have established a new U.S.-China Intellectual Property Experts Group.[32]

In 1998, an agreement was signed between DOE and the NDRC on the peaceful uses of nuclear technologies, with the China Atomic Energy Authority being the implementing agency on the Chinese side. The agreement called for cooperation in such areas as nuclear technology, export controls, materials

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[28] Interview, Shanghai Institute for Applied Physics, January 21, 2014; Interview, Department of Energy, February 18, 2014 and May 30, 2014.
[29] Interview, Ministry of Science and Technology, November 12, 2013.
[30] U.S.-China Clean Energy Research Center, *Annual Report 2012-2013*. *http://www.us-china-cerc.org/resources.html*.
[31] See, for instance, "Intellectual Property, Innovation, and Investment in Clean Energy: Exploring U.S.-China Perspectives," (Second Joint Workshop on Intellectual Property in the U.S.-China Clean Energy Research Center [CERC], Stanford, CA, February 26-27, 2013).
[32] See U.S.-China Clean Energy Research Center, *Annual Report 2012-2013*, pp. 18-19. *http://www.us-china-cerc.org/resources.html*.

protection, control and accountability, safeguards, emergency management, and high-level radioactive waste management. This was followed by an agreement in 2011 with China's National Nuclear Safety Administration and Atomic Energy Authority for the establishment of a nuclear security center of excellence.[33]

DOE activities in the nuclear safety area also augment activities under an agreement between the U.S. Nuclear Regulatory Commission (NRC) and the Chinese National Nuclear Safety Administration, which goes back to 1981 when the NRC entered into an agreement with the State Science and Technology Commission (now MOST). The NRC-National Nuclear Safety Administration agreement has taken on new life with China's decision to build Westinghouse AP 1000 power plants. Under the agreement, China learns from NRC experience and expertise in designing and operating a nuclear regulatory regime. In turn, with China as a pioneer in deploying the AP 1000s, the United States is gaining access to Chinese experience in constructing this latest (third) generation of reactors.[34] Meanwhile, as the world ponders the future of nuclear power and new designs that might safely and economically decarbonize primary energy generation, Chinese research and demonstration projects dealing with fourth-generation nuclear reactor designs, including its "pebble bed" reactor (the world's only operating reactor of this type), are of considerable interest to the U.S. government and U.S. companies.

The Department of Health and Human Services (HHS)

Cooperation in the areas of medicine and public health also goes back to 1979 with the signing of the Protocol for Cooperation in Science and Technology of Medicine and Public Health with China's Ministry of Health (now the National Health and Family Planning Commission), which provided for cooperation in public health, biomedical research, health care, and health policy. The Protocol was renewed most recently in November 2013. The health area has expanded and become quite active in recent years in light of the AIDS epidemic and in the wake of the SARS outbreak in 2002. In 2002, HHS and the Ministry of Health signed an MOU for Cooperation in Fighting HIV/AIDS (also renewed in November 2013) for prevention activities, treatment, and research. As part of the U.S. Emergency Plan for AIDS Relief, activities include research on vaccines, the development of testing kits for rapid diagnosis, monitoring, and innovative treatments.

A second MOU for the Collaborative Program on Emerging and Re-emerging Infectious Diseases was signed by the two parties in 2005. It provides for a higher-profile HHS presence in China with staffing from the Centers for Disease Control and Prevention (CDC), and supports Chinese capacity building through laboratory development, surveillance, enhanced epidemiology, and the establishment of China's own CDC. This agreement was superseded by a new MOU in 2010, which expands cooperation under a new Collaborative Program, establishes a joint committee on collaboration composed of senior officials and experts from both sides, and provides for a joint program office located in the Chinese CDC.

The National Institutes of Health (NIH) are also actively involved with China. Chinese postdoctoral researchers have been consistently the most numerous visiting scientists at NIH laboratories (currently, approximately 700—or about one-third—of the roughly 2000 foreign postdoctoral scientists at the NIH

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[33] DOE also maintains a 2011 MOU with the Chinese General Administration of Customs for the establishment of the radiation detection training center.

[34] Interview, Nuclear Regulatory Commission, December 13, 2013. See also U.S.-China Economic and Security Review Commission, *Hearing on U.S.-China Clean Energy Cooperation: Status, Challenges, and Opportunities*, testimony of Jane Nakano, April 25, 2014.

campus are Chinese).[35] NIH employs one scientist in Beijing who coordinates with the Chinese CDC, the Chinese Academy of Medical Sciences, and the Chinese Academy of Sciences to facilitate research on a variety of diseases, and plays an important role in the implementation of the agreement on emerging and reemerging infectious diseases; some $45 million has been spent by NIH on influenza research in China.[36] In addition, NIH has also had its own long-standing MOU with the Chinese Academy of Sciences for cooperation in basic biomedical research. The MOU was first signed in 1983 and was amended in 2005. Among other things, it calls for jointly funded research training in the United States, and continuing support for researchers once they return to China. Of the 27 institutes at NIH, 18 maintain some form of collaboration with Chinese counterparts.

In October 2010, NIH signed an MOU with the National Natural Sciences Foundation of China (NSFC), the lead Chinese funder of basic biomedical research. This led to a first round of solicitations for joint research proposals in January 2011.[37] 220 proposals were received, and 34 projects were supported in the areas of cancer, HIV/AIDS, allergies, immunology, and infectious diseases. A second joint call was issued in 2011, leading to 176 proposals, of which 48 projects were funded. In the third round, a joint call was issued in May 2012 for work in cancer, HIV/AIDS, allergies, immunology, infectious diseases, mental health, Parkinson's disease, and strokes. In this round, 33 projects were selected from 225 proposals.[38] In August 2013, the two sides agreed on new research programs focusing on HIV/AIDS and heart, lung, and blood diseases.

In addition, the two sides have cooperated in facilitating a Food and Drug Administration (FDA) presence in China under a 2007 agreement with the Chinese General Administration for Quality Supervision, Inspection, and Quarantine, and the establishment of FDA China offices in Beijing, Shanghai, and Guangzhou to support inspections of food and medicine exports to the United States. Plans to increase the number of FDA inspectors based in China, initiated in 2012, encountered problems in October of that year when visas for the new staff were not granted by the Chinese side. The matter was taken up during Vice President Biden’s visit in December, 2013, and FDA was able to secure assurances from the Chinese Government that it would begin granting visas for an increased number of U.S. food and drug investigators stationed in China.[39] At the same time, the United States and China made a commitment to sign an MOU to specify the scope of activity of these personnel. FDA continues to work with its Chinese counterparts to finalize the text of two such MOUs. As of this writing, no visas have been granted; two visa applications are pending before the Ministry of Foreign Affairs awaiting the finalization of the MOUs. Meanwhile, FDA continues to conduct inspections in China through short-term assignments performed by FDA Consumer Safety Officers (CSOs) based in the United States.

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[35] Interview, National Institutes of Health, December 11, 2013.

[36] GlobalHealth.gov, “National Institutes of Health.” *http://www.globalhealth.gov/world-regions/asia-and-pacific/china/national-institutes-health/index.html*.

[37] U.S. and Chinese researchers work together to develop a single proposal, written in English, which is submitted to NIH and NSFC for review. NIH and NSFC issue separate calls for proposals, however. Each side is expected to make substantial intellectual contributions to the work. Normally, the recipients of grants would publish as co-authors in internationally recognized journals, and it would also be possible that they could publish in Chinese journals, as well. Interview, National Institutes of Health, May 5, 2014. See also Department of Health and Human Services, “U.S.-China Program for Biomedical Collaborative Research.” *http://grants.nih.gov/grants/guide/rfa-files/RFA-AI-12-021.html*.

[38] Liu Xiuping (National Natural Science Foundation of China), “NSFC-NIH Collaboration on Biomedical Research,” (Remarks presented at the U.S.-China Executive Secretaries Meeting, October 31, 2013).

[39] U.S.-China Economic and Security Review Commission, *Hearing on China’s Healthcare Sector, Drug Safety, and the U.S.-China Trade in Medical Products* Testimony of Christopher J. Hickey, April 3, 2014.

As HHS continues to understand its mission in global terms, the cooperative relationship with China is a critical part of its mission. China has signed on as a partner, for instance, in HHS's initiative in support of the Global Health Security Agenda.[40]

The National Science Foundation (NSF)

NSF activities with China derive from two long-standing protocols. The Basic Sciences Protocol involves CAS, the Chinese Academy of Social Sciences, the Ministry of Education, and the NSFC. A second Protocol Agreement for Earthquake Studies involves the U.S. Geological Service (USGS) and the National Institute of Standards and Technology (NIST) as well as the NSF on the U.S. side; on the Chinese side, the agreement involves the NSFC, the China Earthquake Administration (formerly the State Seismological Bureau), and the Ministry of Construction. Under the Basic Science Protocol, NSF has supported some 300 projects in a broad range of areas in basic science, engineering, and the social sciences, totaling approximately $32 million during 2012-2013.[41] Under the earthquake agreement, NSF has cooperated with China on projects dealing with disaster prediction and mitigation, structural engineering, and the mitigation of hazards. NSF and NSFC have conducted joint workshops in such areas as earth sciences, material sciences, chemistry, and software, and have issued joint calls for proposals in such fields as socioeconomic dynamics, e-government, chemistry and materials, advanced sensors, and bio-inspired technology.

In recent years, NSF has emphasized the importance of educational programs in its relations with China, and has supported summer research opportunities for U.S. graduate students in China. China also figures prominently in the NSF Partnership for International Research and Education program, which provides for multi-year institutional support for international collaboration involving students and faculty, often on multilateral projects. Through MOST, China participates as an associate member in the NSF Integrated Ocean Drilling Program, and cooperates on a multidisciplinary project on climate change.

The relationship between NSF and NSFC has been especially cordial; NSF helped inspire the establishment of NSFC and has provided ongoing counsel in the management and operation of a basic research-oriented funding agency. In 2004, the two agencies cooperated in convening a forum on basic science for the next 15 years in conjunction with the preparation of China's Medium- to Long-term Plan for scientific and technological development. NSF also sponsors a variety of high-level workshops and symposia in areas of cutting-edge work of interest to the two countries, such as recent workshops on nanoscale standards and computer science.

As a measure of China's growing importance to its work, NSF established a representative office in Beijing in 2006. The visit to NSF in August 2013 by the new NSFC president, Yang Wei (PhD, Brown University), led to an agreement between the two foundations to continue to strengthen work on biodiversity, ecology, and the evolution of infectious diseases; earth-life transitions; environmental sustainability; and support for a next generation of scientists and engineers.[42]

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[40] The Global Health Security Agenda is a partnership of some 30 countries, and is intended to strengthen health preparedness and global responsiveness to threats from infectious diseases and from biological, chemical, radio-nuclear terrorism. See Robert Roos, "U.S. Unveils Plan to Boost Global Health Security," *CIDRAP News*, February 13, 2014. *http://www.cidrap.umn.edu/news-perspective/2014/02/us-unveils-plan-boost-global-health-security*.
[41] Interview, National Science Foundation, December 11, 2013.
[42] Wang Qiang, Liu Xiuping, Nancy Sung, and William Y. Chang, "China-U.S. Collaborations on Basic Research and Education," (Remarks presented at the U.S.-China Executive Secretaries Meeting, October 31, 2013).

NSF continues to have a variety of innovative programs with China on both a bilateral and multilateral basis. Among the latter, the NSF initiative to organize the Global Research Council—intended to promote international research cooperation by developing common understandings of sound research practices and standards—has attracted Chinese participation; CAS hosted the third meeting of the Global Research Council in May 2014. The United States and China also cooperate in promoting the Research Coordination Network for the biodiversity of ciliates that involves researchers from the United Kingdom, Germany, and Brazil, as well as those from China and the United States. NSF is cooperating with NSFC and the Gates Foundation in a program with the Wuhan Botanical Garden of CAS on drought resistance of wheat, a project which also involves Australia and Kenya.

In May 2012, NSF signed an MOU with MOST that is intended to provide a framework in support of international research cooperation. Under this agreement, MOST will entertain funding proposals from Chinese partners on projects supported by the NSF Office of International Science and Engineering. The first project supported by this agreement is the Hot Spring Research Project in Yunnan province, a study of volcanism resulting from tectonic plate collisions. It involves researchers from the University of Nevada, Miami University, the University of Georgia, and Stanford University on the U.S. side, and Chinese researchers from Yunnan University, Tongji University, and the Geosciences University.[43]

Under the NSF agreement with NSFC, the two sides are supporting an innovative study of biodiversity focusing on the resilience of forests to climate change; the study involves a Chinese team from various CAS institutes and U.S. researchers from Harvard University, Michigan State University, and the Smithsonian Institution. The joint biodiversity program is also supporting a new project on ecosystem functions in fragmented landscapes, involving researchers from the Georgia Institute of Technology, Arizona State University, and Zhejiang University. NSF also works with CAS, notably on an important ecological study of Lake Tai involving the University of North Carolina and the Institute of Geography and Limnology of CAS.[44]

In support of more globally aware, next-generation scientists in the United States, NSF works with MOST on the East Asia and Pacific Summer Institutes for U.S. graduate students. Under this program, up to 45 students conduct research in China for two months during the summer. NSF also works with MOST and the Department of State under the People-to-People program (discussed further below) in support of a China-U.S. Young Scientists Forum in conjunction with the Summer Institute.[45]

The National Oceanic & Atmospheric Administration (NOAA)

NOAA conducts activities with China under two protocols, one on Cooperation in the Field of Atmospheric Science and Technology with the Chinese Meteorological Administration, and one on Marine and Fisheries Science and Technology with the State Oceanic Administration (SOA) of China and the Chinese Academy of Fishery Sciences.

NOAA has played an important role in helping to modernize the Chinese agencies through training, instrumentation, and software. Meanwhile, China itself has significantly increased its capabilities with the

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[43] Wang Qiang, Liu Xiuping, Nancy Sung, and William Y. Chang, "China-U.S. Collaborations on Basic Research and Education," (Remarks presented at the U.S.-China Executive Secretaries Meeting, October 31, 2013).
[44] Wang Qiang, Liu Xiuping, Nancy Sung, and William Y. Chang, "China-U.S. Collaborations on Basic Research and Education," (Remarks presented at the U.S.-China Executive Secretaries Meeting, October 31, 2013).
[45] Interview, National Science Foundation, December 11, 2013.

acquisition of more advanced radars, satellites, research vessels, high-performance computers, and increasingly sophisticated basic science. Given its size, location, and topography, China figures prominently in earth observation activities of interest to NOAA, and NOAA's leadership in the science and technologies of earth observation makes it of considerable interest to China. China and the United States are both important members of the World Meteorological Organization, and extend their bilateral cooperation into multilateral settings. China and the United States (along with South Africa and the European Commission) serve as co-chairs of the executive committee of the Group on Earth Observations in support of the Global Earth Observation System of Systems project.[46]

Activities under the atmospheric science protocol are conducted by a joint working group, which met most recently in December 2013. Current activities include work in the areas of climate impacts of greenhouse gases and aerosols, climate and the Asiatic monsoon, numerical weather prediction, meteorological modernization, satellite meteorology, and training.[47]

The marine and fisheries agreement is implemented through a series of working panels. Under a the Data and Information Exchange Panel, three scientists from China's SOA visited the United States from 2012 to 2013, and six U.S. scientists visited China. Cooperation under this panel has led to more than 20 published papers, and a MOU on data assimilation and reanalysis has been signed. The panel's work on the role of oceans in climate change involves exchanges of personnel focusing on tsunami warning and forecasting capabilities. In March 2013, a team from SOA visited NOAA and other marine research facilities to learn about U.S. approaches to ocean renewable energy exploitation and marine observation technology research. The two sides also worked together on carbon cycles and re-analysis of climate change data from Indian Ocean and Southern Ocean[48] research through Chinese visits to the University of Maine and Rutgers University.[49]

The two sides also maintain the Panel on Marine Policy, Management, and International Marine Affairs. In addition to bilateral activities, China and the United States participate in the Asia Pacific Economic Cooperation (APEC) Marine Sustainable Development Center.[50] China hosts the Center at its Third Institute of Oceanography of the State Oceanic Administration in Xiamen, and NOAA is providing training and support opportunities through the International Marine Protected Area Capacity Building Program under its National Marine Sanctuaries program.[51]

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[46] The Group on Earth Observations is a "voluntary partnership of governments and international organizations" seeking to promote international collaboration in the use of earth observations to support decisions on complex environmental problems. With the Global Earth Observation System of Systems project, the group coordinates a variety of observational data to enhance understanding in the areas of disasters, health, energy, climate, water, weather, ecosystems, agriculture, and biodiversity. See *https://www.earthobservations.org*.

[47] William Bolhofer and Zhou Heng, "U.S.-China Protocol for Cooperation in the Field of Atmospheric Science and Technology," (Remarks prepared for presentation at the U.S.-China Executive Secretaries Meeting, October 31, 2013).

[48] The Southern Ocean comprises the southernmost waters of the World Ocean, generally taken to be south of 60°S latitude and encircling Antarctica.

[49] Terry Schaefer and Wang Antao, "Protocol on Cooperation in the Field of Marine and Fisheries Science and Technology between the National Oceanic & Atmospheric Administration of the USA and the State Oceanic Administration of China: Status and Next Steps," (Remarks presented at the U.S.-China Executive Secretaries Meeting, October 31, 2013).

[50] The Center was established in 2011 in response to an APEC Leaders Declaration in support of APEC sustainable development objectives. See *http://www.apecmsd.cn/English/index.aspx*.

[51] National Oceanic & Atmospheric Association, "National Marine Sanctuaries." *http://sanctuaries.noaa.gov/international/regions.html*.

A Living Marine Resources Panel involves cooperation between NOAA's National Marine Fisheries Service and the Chinese Academy of Fisheries Science. In 2012, the Panel identified the following areas for further cooperation: climate impacts on living marine resources; ocean acidification; aquaculture; harmful algal blooms; the monitoring, assessment, and restoration of habitat; and endangered species. The two sides will also attempt to scope out tasks for the joint Indian-Southern Oceans Climatic Observation, Reanalysis, and Prediction program.[52]

Despite overlapping interests and a record of cooperation, Chinese approaches to data sharing—due to the influence of state secrecy laws and proprietary concerns—have long been an irritant to cooperation under both protocols. This has become a greater concern as Chinese capabilities have increased, and with them, U.S. expectations that levels of cooperation offering greater mutual benefit might be reached. As in other areas, some NOAA activities have also been incorporated in S&ED initiatives.

The National Institute of Standards and Technology (NIST)

NIST cooperates with China on several different fronts. It maintains a Protocol on Cooperation in the Fields of Chemistry, Physics, Materials, and Measurement Sciences with CAS. It works with the Chinese General Administration of Quality Supervision, Inspection, and Quarantine under a Protocol on Cooperation in the Fields of Metrology and Standards on issues of metrology, standards, and conformity assessment. Since 2009 NIST has also joined NSF and USGS in the earthquake sciences protocol. These activities have involved approximately 100 Chinese scientists working in NIST laboratories as part of the agency's visiting researcher program (the largest number of foreign researchers at NIST) and various workshops and conferences.

In recent years, several interesting new collaborative projects have been initiated, including one in cooperation with the Chinese National Institute of Metrology on the measurement of greenhouse gases, and ongoing work on the behavior of fires in buildings (for which China provided facilities for fire-induced destructive testing and the United States supplied computer models for data analysis). The Chinese have been very interested in the data acquired from the analysis of the collapse of the World Trade Center towers on September 11, 2001, and have begun to incorporate these data in the construction of major new buildings, including skyscrapers in the new Pudong District of Shanghai. The good working relationships with the National Institute of Metrology have not only been of scientific value, but have also helped common understandings of trade-related standards and conformity assessment issues.[53]

The U.S. Geological Service (USGS)

USGS has been active in China since the 1979 Agreement was signed, and over the years has had agreements for cooperation in water resources, earth sciences, mapping, and nonferrous metals. Because of budget limitations, the levels of activity under some of these agreements have fallen off.[54] As a result, USGS activity in science has focused on earthquakes, volcanology, and earth observations from space.

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[52] Terry Schaefer and Wang Antao, "Protocol on Cooperation in the Field of Marine and Fisheries Science and Technology between the National Oceanic & Atmospheric Administration of the USA and the State Oceanic Administration of China: Status and Next Steps," (Remarks presented at the U.S.-China Executive Secretaries Meeting, October 31, 2013).
[53] Interview, National Institute of Standards and Technology, September 24, 2013.
[54] In 2006, USGS signed a protocol with the China Nonferrous Metals Industry Association that provides for an exchange of mineral demand, production, and consumption data on a yearly basis. This is normally done through

The original earthquake protocol was renegotiated in 2009, with volcanology added at China's request. It now provides for participation of NIST, as well as USGS and NSF on the U.S. side, and names NSFC and the China Earthquake Administration as cooperating parties on the Chinese side. A new protocol with the Center for Earth Observation and Digital Earth (CEODE) of the Chinese Academy of Sciences was signed in November 2010, and builds on prior agreements for cooperation in the use of satellite observations in the earth sciences. USGS also maintains another agreement with CAS on earth observations in connection with the multilateral Committee on Earth Observation Satellites project. In addition, a new protocol was signed in 2009 with the Institute of Space and Earth Information Science of the Chinese University of Hong Kong. A new MOU with CEODE on the use of Landsat 8—the latest earth observation satellite in the Landsat program of space-based land remote sensing data—was recently signed after passing through the Department of State's C-175 process.[55] The agreement provides for the delivery of Landsat data to Chinese earth stations and sets forth the mutual obligations of both parties.

As with NOAA's dealings with China, timely data sharing has also been an irritant in the earthquake protocol. USGS looks to receive seismic data on a real-time basis, but Chinese data security regulations typically lead to 15-minute delays in reporting data. This is in spite of the fact that in the early years of the relationship, the U.S. side provided seismic monitoring stations to China as part of the cooperative program. The data sharing issue is discussed further below.

As the USGS mission evolves, it may be necessary to consider new types of agreements. For instance, the addition of a biological survey mission to USGS opens up possibilities for new forms of cooperation with China. Although these possibilities have been discussed, the Chinese side has yet to determine which agency would be the proper counterpart. The persistence of tight budgets on the U.S. side, however, makes new initiatives less likely and also affects the conduct of existing programs. In some cases, the Chinese side is offering to pay for travel expenses, as well as domestic costs in China, for visiting USGS personnel.[56]

The Environmental Protection Agency (EPA)

EPA maintains agreements with the Ministry of Environmental Protection (MEP), MOST, and the NDRC. An MOU with the Ministry of Water Conservancy was signed in 2007, but is not active due to EPA resource limitations. Similarly, resource constraints have limited the development of activities under a letter of intent for cooperation on energy efficiency in buildings with the Ministry of Housing and Urban and Rural Development, signed in 2008. The initiation of the Ten-Year Framework (TYF) has given greater political prominence to bilateral cooperation on the environment.

The MOU with MEP, first signed in 2003, provides for six working groups dealing with air, water, chemicals, hazardous waste, enforcement and compliance, and environmental law. EPA activities under the TYF for water and air generally follow the activities under the MEP protocol, but the agency also supports some of the other action plans under the TYF, such as those dealing with energy efficiency. The

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USGS visits to China for one to two weeks of exchange with counterpart groups. All data and information gathered is published in the yearly USGS publication on mineral data. Budgetary limits did not permit a visit last year, and make one questionable for this year. U.S. Geological Survey, e-mail message to author, May 27, 2014.

[55] The C-175 process involves a Department of State-conducted interagency review of proposed new agreements. See U.S. Department of State, *Supplementary Handbook on the C-175 Process: Routine Science and Technology Agreements*. *http://www.state.gov/e/oes/rls/rpts/175/*.

[56] Interview, U.S. Geological Survey, February 25, 2014.

MOU with MOST, first signed in 2006, which more clearly deals with research in environmental sciences, was renewed in 2012 with more specific work plans developed in the areas of air, water, and soils. The memorandum of cooperation with the NDRC calls for capacity building efforts to address climate change. EPA has supported activity in managing electronic waste under the S&ED, and the initiation of the new Climate Change Working Group in 2013 will lead to greater involvement under the S&ED mechanism.

In spite of the prominence of environmental issues in U.S.-China relations, EPA is seriously under-resourced given the many demands it faces. Severe budget limitations on travel, for instance, mean that meetings with counterparts are abbreviated and less frequent, thus undercutting the ability to manage and plan cooperative programs. In order to carry out many of its missions, EPA must rely on funding from other sources such as environmental non-governmental organizations (NGOs), the U.S. Trade and Development Agency (TDA), the World Bank, and universities.[57]

Other Agencies

The discussion above captures the activities of most, but not all, of the key technical agencies cooperating with China. The U.S. Nuclear Regulatory Commission has been involved in China for a number of years, and in 2013 renewed its agreement on nuclear safety with the National Nuclear Safety Administration, focusing now on the AP 1000 program. The Fish and Wildlife Service maintains cooperation with the State Forestry Administration in the areas of endangered and invasive species. The National Park Service also maintains contact with the State Forestry Administration and with the Ministry of Housing and Urban and Rural Development. The Department of Transportation maintains programs in China, with the Federal Aviation Administration (FAA) playing an especially active role in promoting air safety and (with the Trade and Development Agency) commercial opportunities for U.S. companies. The U.S. Department of Defense does not have active agreements with China in science and technology, but has had personnel attend conferences in China in high-technology areas, and has had exchanges in areas pertaining to public health, energy, disaster management, and environmental issues.[58]

THE BALANCE OF BENEFITS - A FRAMEWORK FOR ASSESSMENT

Institutional Arrangements for Directing and Managing the Relationship

The chief bilateral governance mechanisms for the U.S.-China S&T relationship are the Joint Commission on S&T Cooperation (JCM) and the S&T Executive Secretaries Meeting (ESM). These have been in place since the Agreement was first signed, and although there are no immediate plans to alter them, several questions about their operation can be raised.

The S&T relationship has become a very complex, multifaceted pattern of engagement between the two countries involving not just government-to-government programs, but also commercial and academic interactions, which arguably are more extensive and, in some ways, are more consequential for the development of Chinese academic science, industrial technology, and human resources.[59] This raises the

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[57] Interview, Environmental Protection Agency, February 26, 2014.

[58] U.S. Department of State, Bureau of Oceans and International Environmental and Scientific Affairs, Office of Science and Technology Cooperation, “United States-China Science and Technology Cooperation,” *Biennial Report to the United States Congress*, July 2012.

[59] The same could be said in assessing the consequences of the relationship for the United States. With Chinese graduate students constituting the largest number of foreign recipients of Ph.D.s in science and engineering granted

questions of whether senior policy makers are afforded a comprehensive view of the totality of S&T interactions between the two countries and whether stakeholder views from the commercial and academic communities are adequately represented in the existing arrangements.

In some ways, effective overviews and representation do exist, given the ties that the White House's Office of Science and Technology Policy (OSTP) maintains with non-governmental communities via the President's Council of Advisors for Science and Technology, which includes representatives from businesses and universities. On the other hand, this is a rather indirect and limited mechanism. It does not provide opportunities for synoptic overviews of the broad range of bilateral activities, and does not provide opportunities for representatives from the business and academic worlds to share experiences and engage Chinese counterparts directly in an official governmental context over issues that increasingly cut across governmental, commercial, and academic boundaries.

Second, coordination *within* the two governments can be problematic. On the U.S. side, coordination occurs in a fashion that is more decentralized than in China, which sometimes makes the development of an overall strategic vision difficult. Reportedly, focused interagency coordination is driven largely by the need to prepare for JCM and ESM meetings, not as a regular process of policy management. For ESM meetings in particular, the level of enthusiasm for participation varies considerably by agency.[60] Interagency coordination is also evident in the C-175 process by which technical agencies have to secure Department of State clearance for new initiatives.[61] Preparation by the Department of State of its biennial report to Congress on the U.S.-China S&T relationship mandated by the Bob Stump National Defense Authorization Act for Fiscal Year 2003 (Public Law 107-314) also provides an opportunity for a centralized overview of agency experiences. The level of detail and depth of analysis in these reports, however, have varied considerably over the years.

U.S. budget uncertainties also limit the ability to plan in ways that would enhance agency interests and, arguably, national interest more generally. At the OSTP level and within the Department of State, providing adequate staff for S&T relations with China has long been a challenge. In this context, Congressional efforts to constrain the activities of OSTP may further weaken U.S. ability to develop the

by U.S. universities, and the historically high rates of Chinese staying and making careers in the United States, U.S. university faculties have been enriched by Chinese talent and U.S. companies doing business in China have been provided high-level, bicultural technical personnel.

[60] Interviews with agency officials, October-November 2013.

[61] In spite of the efforts to streamline the C-175 process, in at least one case the conclusion of an agreement has been pending for approximately 18 months.

kind of robust strategic orientation that engagement with an increasingly capable and well-resourced China seems to require.[62]

Staffing in the technical agencies also warrants consideration. Those charged with administering relations with China—typically in agency international affairs offices—are often faced with multiple competing responsibilities involving other countries. Further, there is considerable variability in the availability of staff personnel with technical backgrounds and/or Chinese language skills, which are qualities that are likely to provide better insights into the operation of the Chinese counterpart agencies.

Although staffing on the Chinese side is often characterized by the use of international affairs generalists, in some agencies this is not the case. The Chinese Meteorological Agency, for instance, requires that those engaged in relations with the United States have degrees in meteorology. And, among the generalists, one typically sees individuals who have had sustained experience working the "American account," have the necessary English language skills, and have followed significant S&T trends in the United States.

The growth and complexity of the S&T relationship have led to a considerable increase in U.S. personnel at the Embassy in Beijing. In addition to the science counselor's office operated by the Department of State, and the NSF Beijing office, a number of other technical agencies—including DOE, USDA, HHS, and (FAA)—maintain staff in Beijing. Considerable staff time, however, is given to arranging and managing visits from U.S. officials, and interacting with home offices, with less time for visits to Chinese facilities and in-depth reporting on trends in China of relevance to the relationship. Again, there is wide variation in Chinese language facility and/or technical backgrounds among the staff.

On the Chinese side, the existence of a dedicated ministry for science and technology with a specialized bureau for international affairs seemingly provides a more effective mechanism for managing the relationship with vision and a sense of national purpose. MOST represents China at the JCM, and its

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[62] Although the S&T relationship with China is conducted largely by the executive branch, Congressional concerns over the relationship, particularly related to Chinese state-sponsored commercial espionage, have increased in recent years. These concerns are evident in limitations placed on the work of OSTP and the National Aeronautics and Space Administration (NASA) as a result of Congressman Frank Wolf's initiatives as reflected, for instance, in the 2014 Consolidated Appropriations Act, according to which,

> "(a) None of the funds made available by this Act may be used for the National Aeronautics and Space Administration (NASA) or the Office of Science and Technology Policy (OSTP) to develop, design, plan, promulgate, implement, or execute a bilateral policy, program, order, or contract of any kind to participate, collaborate, or coordinate bilaterally in any way with China or any Chinese-owned company unless such activities are specifically authorized by a law enacted after the date of enactment of this Act.
> (b) None of the funds made available by this Act may be used to effectuate the hosting of official Chinese visitors at facilities belonging to or utilized by NASA.
> (c) The limitations described in subsections (a) and (b) shall not apply to activities which NASA or OSTP has certified—
>
> > (1) pose no risk of resulting in the transfer of technology, data, or other information with national security or economic security implications to China or a Chinese-owned company; and
> > (2) will not involve knowing interactions with officials who have been determined by the United States to have direct involvement with violations of human rights.
> > (d) Any certification made under subsection (c) shall be submitted to the Committees on Appropriations of the House of Representatives and the Senate no later than 30 days prior to the activity in question and shall include a description of the purpose of the activity, its agenda, its major participants, and its location and timing." See HR 3547-81, § 532.

Department of International Cooperation serves as its secretariat. As the designated ministry for science and technology, MOST has authority for national S&T policy, including the development of policies for international cooperation, and is thus in a position to integrate Chinese activities with the United States and domestic science and technology development plans.

When the history of the bilateral relationship is considered, the two sides appear to have approached the relationship with somewhat different objectives, and the respective institutional mechanisms reflect these differences. On the U.S. side, building the S&T relationship was seen as part of a diplomatic initiative to normalize relations with China, especially in light of Cold War challenges from the Soviet Union.[63] That the executive secretary function is located in the Department of State, a foreign affairs (rather than a technical) agency, in part reflects the fact that S&T cooperation has been seen as a tool of diplomacy. Although science diplomacy has gradually acquired a greater weight within the Department of State, it still occupies a subordinate position in comparison with the Department's political, security, and economic missions, and this has affected staffing of China-related S&T matters. Although staffing has been strengthened by the addition of American Association for the Advancement of Science fellows and technically trained officials appointed to civil service (in contrast to Foreign Service) positions, work on the U.S.-China S&T relationship competes with programs with other countries or other Department of State missions.

On the Chinese side, on the other hand, the assumption has been that engagement with international science and technology—and especially with the United States—is an important national project for catching up with the international scientific and technological frontiers, especially after setbacks resulting from the years of the Cultural Revolution.[64] As a result, dedicated funds are available to support international cooperation, and specialized staffs have been set up in technical agencies to promote international cooperation to enhance national S&T capabilities. While science diplomacy considerations have not been entirely absent, especially with regard to Chinese relations with the developing world, the orientation has been very much toward the use of S&T cooperation in building national capabilities.[65] To this end, China has developed much more of a strategic orientation toward the bilateral relationship with the United States in ways that are difficult to accomplish in the U.S. setting given the separation of

[63] For a useful discussion, see Jin Xiaoming, "The China-U.S. Relationship in Science and Technology" (Conference on China's Emerging Technological Trajectory in the 21st Century, Rensselaer Polytechnic Institute, September 4-6, 2003). *http://china-us.uoregon.edu/papers.php.*

[64] Jin, "The China-U.S. Relationship in Science and Technology."

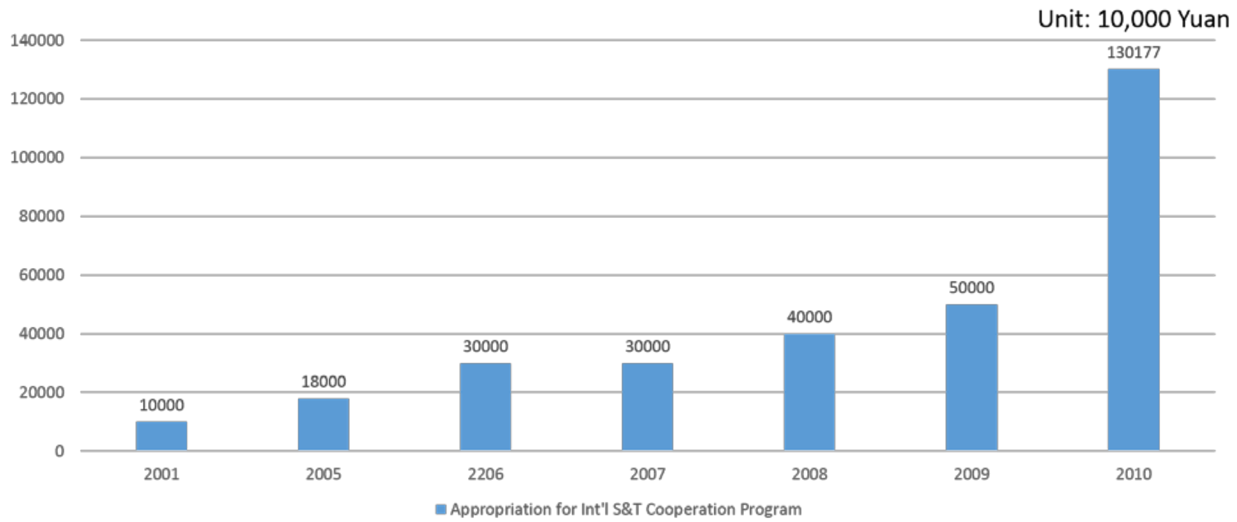
[65] The U.S.-China Innovation Dialogue also illustrates the differing approaches the two sides bring to the relationship. With the initiation of its Medium- to Long-Term Plan in 2006, China has made "innovation" a key national objective, and introduced a series of R&D and supporting industrial policies intended to promote national innovation capabilities under the rubric (until recently) of "indigenous innovation." These policies impacted foreign trade and investment practices, which disadvantaged foreign stakeholders. U.S. unhappiness with Chinese policies made its way to the agenda of the S&ED, where the decision was made to initiate a "two-track" dialogue on innovation. With its aspirations for innovation, and its admiration of the U.S. innovation system, the Chinese side agreed that the initiation of a new dialogue on innovation would make sense. The U.S. side, however, saw the dialogue as a way to address its trade and investment concerns growing out of China's indigenous innovation policies. On the Chinese side, the interest was much more that of learning about U.S. best practices and sharing Chinese experience with innovation. Although the leadership of the dialogue now rests with OSTP on the U.S. side, and innovation itself has moved more clearly to the center of the dialogue, it continues to be an avenue for pursuing trade and investment policy concerns on the U.S. side, in keeping with U.S. traditions of using science and technology for diplomatic ends, in contrast to the more technical innovation policy concerns on the Chinese side. See, for instance, the discussion of the Innovation Dialogue in the U.S. Department of State, *2014 Biennial Report to Congress*, p. 5.

powers and the relatively decentralized nature of the U.S. system. In the absence of a Department of Science and Technology, the United States must work to achieve strategic purpose and action through decentralized coordination and through the work of strong executive support agencies.

This is not to say that national coordination is inherently superior in China. MOST is not alone in driving the bilateral S&T relationship, as seen in the initiatives from CAS and NSFC and the variety of other ministries and agencies represented in the protocols and MOUs noted above. Although in 2007 MOST organized an interministerial coordinating body, which now has 23 members, Chinese bureaucratic stove-piping problems are widespread, and bureaucratic competition for opportunities for international cooperation can—and do—at times impede the development of programs of cooperation.[66] That said, China's ability to develop international S&T strategies, incorporate them into plans, and make resources available for plan implementation has, overall, served it well. This is especially true in the context of China's ambitious Medium- to Long-Term Plan for science and technology (2006-2020), which has incorporated international scientific cooperation as a major component and, with it, has made a significant commitment of financial resources, as seen in Figure 1.

[66] Wang Zhongcheng, "The Structure and Organization of China's International S&T Cooperation (ISTC) System: National and Local Level Perspectives," (Remarks at the Conference on China's International S&T Relations: A Stocktaking and Assessment, Arizona State University, April 3-4, 2014). The CERC program illustrates some of the major differences between Chinese and U.S. approaches to the implementation of international programs. Once the agreement to proceed with the program was reached at the political level, on the U.S. side DOE solicited proposals for the formation of the three U.S. consortia, which led to a process by which interested parties in universities, companies, and government laboratories explored on a voluntary basis common interests and a willingness to cooperate. The absence of any kind of command decision meant that the process took some time, but also engendered commitment to the program. On the Chinese side, the government took a more active leadership role, with the state attempting to select the various parties to the consortia. This process was characterized by considerable bureaucratic contestation among several agencies, which also took time to resolve.

Figure 1: Chinese Central Government Appropriation for International S&T Cooperation Programs



Source: China S&T Yearbook

A further indication of the more strategic orientation on the Chinese side is seen in the 2011 national conference on international science and technology affairs, and the formulation of an action plan for international S&T cooperation during the 12th Five-Year Plan period (2011-2015), which lays out a set of priorities for China's international S&T.[67] The plan also calls for the further development of "international S&T cooperation bases" (innovation parks, joint research centers, technology transfer centers, and centers for demonstrating international cooperation best practices), and it includes international talent recruitment programs. It is also notable that the Chinese central government has begun to work with provincial and subprovincial governments to encourage them to develop international S&T strategies.[68]

MOST has not been hesitant in building relations with leading foreign technology companies as part of its overall international strategy, and it maintains several support agencies that enhance its strategic orientation. These include the China Science and Technology Exchange Center, the existence of which extends MOST's staff capabilities, and the Institute for Scientific and Technical Information of China. The latter, along with the Library of CAS, engages in monitoring and analysis of scientific and technological trends, identifies international centers of excellence, and provides assessments of the

[67] At this meeting, Minister of Science and Technology Wan Gang identified four main international cooperation objectives for the 12th Five-Year Plan period. These included improving S&T cooperation between governments, strengthening the relations between international cooperation and Chinese national S&T planning, enhancing the role of China in major international S&T organizations, and taking a more active role in using S&T for foreign assistance. Denis Fred Simon, "The Changing Face of China's International S&T Relations," (Presentation at the University of Twente, Enschede, Netherlands, October 2012). *http://www.utwente.nl/igs/conferences/2012-snet/presentations/presentaties/1501/24102012_simon.pdf.*

[68] Wang Zhongcheng, "The Structure and Organization of China's International S&T Cooperation (ISTC) System: National and Local Level Perspectives," (Remarks at the Conference on China's International S&T Relations: A Stocktaking and Assessment, Arizona State University, April 3-4, 2014).

strengths and weaknesses of Chinese science and technology vis-à-vis other countries. With large and increasingly sophisticated staffs, they provide important informational and analytical bases for the development of international S&T strategies in ways that the United States, with its more decentralized system, seems less equipped to do.[69]

China's commitment to the development of an international S&T strategy has produced some intriguing results. The recently completed Battelle and *R&D Magazine* 2014 Global R&D Funding Forecast notes, for instance:

> "While taking its place among global R&D leaders, China recognizes the leverage available through international collaboration. Many of China's R&D programs involve collaborations with European and/or U.S. research organizations. According to the Battelle/*R&D Magazine* Global Researchers Survey, about a third of China's advanced R&D is pursued in collaboration with U.S. research organizations and about a quarter in collaboration with European research organizations."[70]

Intellectual Property Rights (IPR) Challenges

Since 1991, IPR issues have been handled under the terms of Annex 1 of the S&T Agreement, reference to which has been incorporated in most subsequent or renewed protocols and MOUs. Since most areas of cooperation have focused on nonproprietary science and technology in support of public goods, though, IP concerns have not been prominent. However, as Sino-U.S. cooperative activities under the Agreement come to be characterized by greater industry participation and public-private arrangements, IP is becoming more important.

This is especially well-illustrated in the case of CERC. The building of the public-private consortia, which characterize the CERC initiative, required that IPR issues be given high priority. As a result, a special IPR Annex that builds on—but departs from—the language of Annex 1 of the Agreement was made part of the protocol.[71] During the first two years of the program, efforts were focused on the development of common understandings about intellectual property, the results of which have now been incorporated into the technology management plans used by the consortia in developing new projects.

With regard to patenting under the Agreement, the CERC experience is again instructive. The CERC 2012-2013 Annual Report notes, for instance, that projects under the Advanced Coal Technology Consortium have generated 17 patents, while the Clean Vehicles Consortium projects have led to 20 patents and invention disclosures in the United States and 12 patents in China.[72] Slightly different numbers, reflecting greater patenting activity on the Chinese side, are found in a recent paper by Joanna I. Lewis, as seen in Table 1.[73]

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[69] cf., William C. Hannas, James Mulvenon, and Anna B. Puglisi, *Chinese Industrial Espionage* (London and New York, NY: Routledge, 2013), Chapter 2.
[70] Battelle and *R&D Magazine*, "2014 Global R&D Funding Forecast," December 2013, p.15.
[71] Two critical areas illustrating the new directions are provisions for protecting "background IP" (IP that existed prior to the initiation of a cooperative project, in contrast to "project IP" resulting from the project) and provisions for exploiting the IP in each other's territory.
[72] U.S.-China Clean Energy Research Center, *Annual Report,* 2012-2013.
[73] Joanna I. Lewis, "Managing Intellectual Property Rights in Cross-Border Clean Energy Collaboration: The Case of the U.S.-China Clean Energy Research Center," *Energy Policy* 69 (June 2014): 546–554. As Lewis notes, accurate patent data is always somewhat elusive depending on sources and the timing when data was collected.

Table 1: Patents Resulting from CERC Activities

CERC Consortium	Patents filed in China by Chinese participants	Patents filed in the US by Chinese participants	Patents filed in the US by US participants	Patents filed in China by US participants
ACTC	12	0	3	0
BEE	10	0	2[a]	0
CVC	12	11	20[a]	0
Subtotals	*34*	*11*	*25*	*0*
Total Patents Filed by Chinese CERC Members	45			
Total Patents Filed by US CERC Members	25			

Notes: Includes invention disclosures. Due to discrepancies in data as reported across multiple sources, patent reports should be treated as estimates. Data collected through October 2013.

ACTC – Advanced Coal Technology Consortium
BEE – Building Energy Efficiency
CVC – Clean Vehicles Consortium

At this point, no IPR disputes in the CERC program have been reported after the completion of the technology management plans, but Lewis notes that in many ways the provisions have not been tested, even though on paper they do provide for processes to determine how benefits of IP creation should be shared.

Technology Leakage and Security Concerns

For the most part, the government-to-government relationship is not a conduit for the transfer of sensitive technologies, especially technologies embedded in physical artifacts. The fact that the relationship *does* involve training and visits to U.S. laboratories, however, ensures that knowledge transfers occur. U.S. concerns over the course of the last decade about “deemed exports” and “human embodied” transfers of sensitive scientific knowledge or technology have led technical agencies to put in place mechanisms to vet visiting scientists and engineers. [74] Overall, however, the government-to-government relationship is much less a conduit for technology transfer than commercial relations or academic channels.

Security concerns have become far more prevalent in the relationship now than in the past, in large part due to various political tensions between the two countries and China’s rise as a commercial and potential military competitor. Allegations of cyberespionage activities made by both sides against the other further highlight the increasing prevalence of information security issues. In particular, concerns over Chinese

[74] The term “deemed export” refers to the transfer of technology or source code to a foreign national within the United States. See Department of Commerce, Bureau of Industry and Security, “Deemed Exports.” *https://www.bis.doc.gov/index.php/policy-guidance/deemed-exports*. “Human embodied technology” refers to technical know-how possessed by a person, in contrast to technology embodied in machinery, code, or blueprints.

espionage and technology acquisition strategies have led to greater wariness in the conduct of relations on the U.S. side in the face of reports from several agencies that Chinese interests in scientific collaboration seem to be targeted at specific fields and facilities where China hopes to enhance capabilities.[75]

A less-than-transparent state secrecy legal environment on the Chinese side has led to limitations on data sharing under certain protocols. This has led to U.S. frustrations over the conduct of field research in ways that are inconsistent with the culture of scientific openness with which U.S. officials and investigators are familiar.[76] As a further sign of deepening security concerns on the Chinese side, the recently formed Central National Security Commission has included science and technology as one of 11 areas for which state security must be strengthened.[77] How this development will affect U.S.-China cooperation remains to be seen.

From a Chinese perspective, U.S. export controls and visa processes (though much improved) are also manifestations of a security consciousness that is not always consistent with open scientific practices. A recent controversy over the prohibition of Chinese participation in the NASA Ames Research Center meeting to discuss the findings from the Kepler interplanetary survey mission illustrates this tension.[78]

It has long been assumed by the U.S. side that Chinese intelligence agencies play a key role in identifying technology acquisition targets, which are then shared with civilian S&T agencies as well as national security agencies.[79] Since this report is being prepared on an unclassified, open source basis, it is not possible to determine the extent to which such technology acquisition targeting enters into the S&T relationship under the Agreement other than to note that several U.S. agencies have expressed concern during interviews with the author about what appears to be Chinese targeting of selected laboratories and fields of study for cooperative activities.[80] Several recent cases do illustrate that S&T cooperation, as discussed further below, is not immune to espionage.[81]

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[75] Interviews with U.S. officials, December 2013 and February 2014.

[76] Under China's State Secrets Law, there are various regulations dealing with surveying and mapping, marine scientific research, foreign-related meteorological observations, and data management, etc., which deter Chinese counterparts from being able to be as open with data as they might want. For a discussion of the ambiguity and lack of transparency in the state secrets system, see Human Rights in China, *State Secrets: China's Legal Labyrinth* (New York, NY: Human Rights in China, 2007). *http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=3&ved=0CDcQFjAC&url=http%3A%2F%2Fwww.hrichina.org%2Fsites%2Fdefault%2Ffiles%2FPDFs%2FState-Secrets-Report%2FHRIC_StateSecrets-Report.pdf&ei=62gkU4arGeu70AGBw4HIAw&usg=AFQjCNHOsrThWexwuNip9bZzF6lHUmDEWQ&bvm=bv.62922401,d.dmQ*.

[77] Willy Lam, "Terrorism Fears Push Muscular Approach to 'Overall National Security,'" *China Brief* 14 (May 7, 2014). *http://www.jamestown.org/programs/chinabrief/single/?tx_ttnews[tt_news]=42329&tx_ttnews[backPid]=25&cHash=5c1918a6e2db65e194890b60f724a70a#.U3ULZChhstU.*

[78] Jeffrey Mervis, "NASA Meeting Bars Chinese Students," *Science* 342 (11 October, 2013): 177.

[79] For a recent discussion, see William C. Hannas, James Mulvenon, and Anna B. Puglisi, *Chinese Industrial Espionage* (London and New York, NY: Routledge, 2013), Chapter 2.

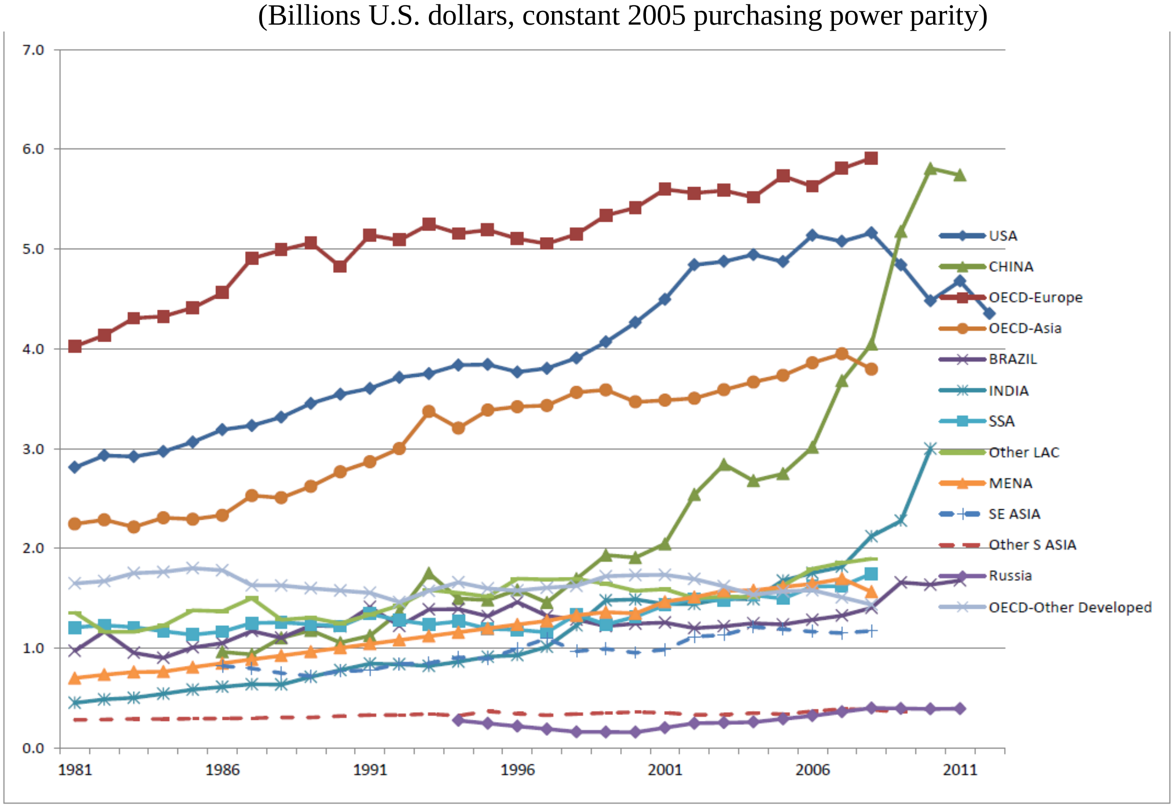
[80] Interviews with U.S. officials, December 2013 and February 2014.

[81] For instance, Tom Hays, "NYU Researchers Took Bribes from Chinese Company, Feds Say," *Huffington Post College*, May 20, 2013. *http://www.huffingtonpost.com/2013/05/20/nyu-researchers-took-bribes-from-china-feds_n_3308401.html*.

Finance

On the Chinese side, dedicated funding for international cooperation, seen as a critical investment decision, has long characterized its approach to the relationship. This was true even when China was a far poorer and less developed nation than it is today. Although the new Xi Jinping government is approaching the funding of S&T with a far more skeptical eye than its predecessors, it has nevertheless pledged to increase the central government's expenditure on S&T by 8.9 percent in 2014, to some $43.6 billion, with basic research increasing by 12.5 percent. After increasing by 23 percent per year, on average, over the past decade, China now trails only the United States in the financial commitments it makes to R&D.[82] And, at least in public support for agricultural R&D, China has pulled ahead of the United States, as seen in Figure 2.

Figure 2: Global Public Agricultural Research Spending
(Billions U.S. dollars, constant 2005 purchasing power parity)



Source: USDA Economic Research Service, unpublished.

With its expanding wealth and commitment to S&T development, China is building a number of world-class facilities that are of considerable interest to scientists from abroad, including Americans, and this should be supportive of new forms of international cooperation.

On the U.S. side, the establishment of dedicated funds for international cooperation, including cooperation with China, has been resisted. Instead, a long-standing principle for most agencies has been

[82] Jane Qiu, "China Goes Back to Basics on Research Funding," *Nature* 507 (13 March, 2014): 148-149. See also Battelle and *R&D Magazine*, "2014 Global R&D Funding Forecast," December 2013.

that cooperative activities with China must serve agency missions, must be justified on those grounds, and therefore must come out of regular agency budgets. Since the missions of many U.S. agencies are now broadly internationalized, finding a justification for committing financial resources for work with China is less of a challenge than it once was, especially given China's growing prominence in science and its role in the global commons problems that form part of the portfolios of the technical agencies. But, while the justification is there, budget stringency, and especially the budgetary uncertainty of the last few years, have affected the conduct of the relationship. This is true with regard to staffing, to travel and the performance of activities under the various agreements, and to the development of prospective, strategic, forward thinking that might better serve U.S. interests.

Meanwhile, China's willingness to fund an increasing share of cooperative activities, while certainly welcome, nevertheless points to the possibility of a changing balance of influence in the bilateral relationship, and to the likelihood of enhanced Chinese influence in multilateral affairs.

The Broader Picture of U.S.-China S&T Relations

In some ways, the different channels through which U.S.-China S&T cooperation occurs are quite distinct. While the overall S&T Agreement has provided a framework for other sectors, the drivers for cooperative activities in industry and universities are, in varying degrees, different from the government-to-government relations provided for by the Agreement. From the discussion above, one can see that activities through the government-to-government channels tend to be supportive of government missions (public health, agriculture, environmental protection, basic research, etc.) and fall largely into a category that might be referred to as "science and technology in support of public goods."

Activities within industrial channels, on the other hand, focus much more on the profitable appropriation of value from scientific and technical knowledge, especially with regard to high technology and science-based industries. These activities are pursued, at least on the U.S. side, by private companies that are subject to trade and investment agreements between the two governments (largely through the Joint Commission on Commerce and Trade), and to a variety of domestic laws in both countries, including those pertaining to export controls, foreign investment practices, intellectual property law, competition policy, etc. Cooperation in the commercial sector involves various forms of technology transfer undertaken as business decisions and, over the past 15-20 years, the establishment of R&D activities in China. And as Chinese companies expand internationally, they are pursuing a variety of technology acquisition strategies ranging from mergers and acquisitions, contract research with foreign universities and research centers, the establishment of their own R&D centers abroad and, at times, the use of various forms of surreptitious acquisitions.

Activities through academic channels often focus more on basic science and the ways in which cooperative research activities advance educational missions. However, as universities attempt to internationalize engineering education, and establish cooperative programs with Chinese counterparts to that end, the knowledge flows that result are not limited to basic science.[83] While these activities occur largely outside of a U.S. regulatory framework, and depend on the initiatives of individual scientists and engineers, and on colleges and universities as institutions, some government policies do extend to

[83] For example, in 2013 the College of Engineering of the University of California, Berkeley, established the Shanghai Zhangjiang Berkeley Engineering Innovation Center in the Zhangjiang High-Tech Park in cooperation with the park authorities and the Shanghai government. See Berkeley College of Engineering, "College of Engineering Opens Innovation Center in Shanghai," Nov 15, 2013. *http://coe.berkeley.edu/news-center/press-releases/college-of-engineering-opens-innovation-center-in-shanghai*.

activities in academic channels, including heightened attention to deemed exports.[84] In the latest stage of the development, ties through academic channels are moving from cooperation between individual scientists, or teams of investigators, to more institutionalized arrangements such as the establishment of branch campuses and representative offices as ways of demonstrating a university presence on Chinese soil.

Various professional societies also maintain relations with Chinese counterparts, including the National Academies (mainly through relations with CAS and the Chinese Academy of Engineering) and the American Association for the Advancement of Science (mainly through its counterpart, the China Association for Science and Technology). Although most of these nongovernmental relationships with China largely fall outside the purview of the Agreement, governmental and nongovernmental programs do interact in several important ways. For instance, with support from NSF and NIH on the U.S. side, the U.S. National Academy of Sciences and the Chinese Academy of Sciences maintained a U.S.-China Roundtable on Scientific Data Cooperation from 2006 to 2011.[85] The two sides plan to resume discussions in 2014 with support from the Secure World Foundation. In the energy and environmental areas, NGOs such as the National Resources Defense Council and Energy Foundation China work with government agencies in the implementation of cooperative programs.[86] University programs get linked to the Agreement through the funding of extramural research by those agencies that support it, including NSF, USDA, DOE, and NIST.

Both sides have expressed support for expanding public-private partnerships under the Agreement and it is likely that—in at least some programs—government initiatives will be mixed with the interests of industrial, academic, and NGO stakeholders in new ways. The CERC case provides one interesting manifestation of this trend. With this growing appeal of public-private partnerships, we are also seeing the involvement of the U.S. Trade and Development Agency, which is cooperating with U.S. technical agencies, sharing costs, and cooperating to support U.S. commercial exports. For instance, TDA funded a program on air quality management in China developed in cooperation with EPA. By introducing Chinese

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[84] In response to evolving thinking about deemed exports and universities, universities have hired staff to ensure compliance with export control regulations, and have attempted to raise awareness on campus through the addition of export control materials to their websites. In 2005, the Federal Bureau of Investigation (FBI) organized the National Security Higher Education Advisory Board (NSHEAB), which comprises the presidents of some 25 universities, to maintain a liaison with universities on national security matters pertaining to higher education. See Federal Bureau of Investigation, "The FBI's College and University Security Effort." *http://www.fbi.gov/about-us/investigate/counterintelligence/us-academia*. The FBI also maintains an ongoing program, the College and University Security Effort (CAUSE), and in 2011 issued a report on Higher Education and National Security (*http://www.fbi.gov/about-us/investigate/counterintelligence/higher-education-and-national-security*). In the case of the Shanghai Zhangjiang Berkeley Engineering Innovation Center, the relevance of intellectual property and export control concerns is recognized. Berkeley College of Engineering, "Questions and Answers: The Shanghai Zhangjiang Berkeley Engineering Innovation (Z-BEI) Center." *http://coe.berkeley.edu/news-center/press-releases/berkeley-engineering-in-shanghai-faq.html*.

[85] See National Academy of Sciences Board on Research Data and Information – Policy and Global Affairs, "U.S.-China Roundtable on Scientific Data Cooperation." *http://sites.nationalacademies.org/PGA/brdi/PGA_047350*.

[86] Natural Resources Defense Council, "China Activities." *http://www.nrdc.org/search.asp?cof=FORID%3A11&ie=UTF-8&q=china+activities&cx=001024953138106184952%3Alevppyfplwy&hq=-inurl%3Ahttps&t=iframe*. Energy Foundation China. *http://www.efchina.org/*.

officials to U.S. best practices and technologies, the program is intended to enhance the prospects for the sale of U.S. environmental technologies.[87]

On the U.S. side, national coordination of activities through these various channels, to the extent it exists, is largely informal and often the result of common professional interests. High-level opportunities for oversight exist at OSTP, where the President's Science Advisor typically will be engaged professionally with stakeholders from the different sectors and, as chair of the President's Council of Advisors on Science and Technology (PCAST) and the National Science and Technology Council (NSTC), has regular contact with industry and university leaders (who are members of PCAST) and senior technical officials from executive agencies (members of NCST).

On the Chinese side, many government ministries maintain their own research institutes and institutions of higher education. Hence Chinese participation in bilateral programs often come from these institutions as well as from CAS. Researchers from Chinese universities also cooperate with U.S. counterparts through investigator-initiated projects with funding from programs operated by NSFC, MOST, and other ministries. Since most Chinese funding programs have some degree of top-down guidance, the participation of Chinese scientists at times reflects these top-down objectives. In certain areas (e.g., "big science" such as high-energy physics) that use large, expensive facilities involving CAS units, the driving forces of national policy objectives, organizational interests, and investigator motivations often become intermixed. The substantial resource commitments required for such facilities can be made only when the power and interests of the state are aligned with scientific curiosity. The development of a national strategy for international S&T by MOST is intended to lead to better coordination and more concerted action among governmental, industrial, and academic interests.

In the past, Chinese state-owned enterprises generally have not been active participants in the S&T relationship under the Agreement, although many have been actively engaged in technology transfer relations with U.S. companies through commercial channels. There have been exceptions, though, especially in an area like fossil energy technology, where state companies are the technological leaders in China. As China seeks to promote a more enterprise-focused innovation system, and as new initiatives from both sides seek to find projects characterized by some form of public-private participation, the role of state-owned enterprises is likely to increase.[88] In the case of CERC, for instance, the industrial representation in the Chinese consortia includes not only state-owned enterprises, but also important private energy companies such as ENN (or, in Chinese, XinAo Group).

Since the normalization of relations between the United States and China in 1979, there have been a variety of people-to-people activities involving state and local governments, professional societies, and clubs in the S&T community. While some of these have involved scientists and engineers—especially if we include the activities of professional societies in the people-to-people category—most have not involved S&T and fewer still actually involved scientific cooperation. More recently, the two countries have initiated the U.S.-China Consultation on People-to-People Exchange which has exchanges in S&T

[87] TDA activities have also included cooperation with the Department of Transportation, DOE, and USDA, for instance. See United States Trade and Development Agency, "USTDA in China" *http://www.ustda.gov/program/regions/eastasia/*. See also U.S.-China Economic and Security Review Commission, Hearing on *U.S.-China Clean Energy Cooperation: Status, Challenges, and Opportunities*, statement by Leocadia I. Zak, Director U.S. Trade and Development Agency, April 25, 2014.

[88] China's current leadership has indicated it wants to reconfigure the relationships between SOEs and private firms by reducing many of the policy privileges of the former, which is likely to affect the technology strategies of SOEs in ways that are still somewhat unclear.

as one of its five programs. This program, administered by the Department of State on the U.S. side and MOST on the Chinese side, focuses on career development issues for young scientists (with cooperation from NSF) and on issues having to do with public understanding and appreciation of science. The Consultation on People-to-People Exchange enjoys high-level political endorsement, but at this point there is no way to readily assess the consequences of these exchanges for the development of Chinese S&T capabilities.

That China has learned from these various people-to-people initiatives over the years is quite likely; that the learning is of strategic significance is less likely. On the other hand, the flow of Chinese students and scholars to the United States and back to China has undoubtedly contributed a great deal to the development of Chinese S&T over the past three decades. Individuals returning to China bring knowledge not only of their scientific and engineering fields, but also of the policy and institutional environment for successful research and innovation to which they were exposed in the United States. Many of these individuals have gone on to leadership positions in Chinese research institutes and universities. Many other Chinese scientists and engineers have stayed in the United States and made professional careers there. In a number of fields, these individuals have organized ethnic Chinese professional societies, which often have as part of their mission the rendering of support for S&T development in China.[89] Most members of this professional diasporic community have become productive professionals contributing to U.S. research and innovation enterprises; as we know, though, a few individuals have been active agents in transferring technology in violation of U.S. export control laws or laws intended to protect intellectual property.[90]

A complex and inadequately understood aspect of the expansion of international scientific and technological cooperation is the role played by ethnically based diasporic communities (Indian, Russian, Israeli, and others, as well as Chinese).[91] There is little doubt that common ethnicity plays an important part in U.S.-China S&T cooperation in all channels of engagement—industrial, academic, and governmental. Chinese researchers working in the United States often maintain contacts with institutions in China and are happy to have Chinese graduate students in their laboratories. China maintains a number of formal incentive programs to attract Chinese scientists back to China, and can reward Chinese scientists working in the United States in a variety of ways with material and nonmaterial appeals to

[89] Richard P. Suttmeier, "State, Self-Organization, and Identity in the Building of Sino-U.S. Cooperation in Science and Technology," *Asian Perspective* 32, 1 (2008): 5-31.
[90] See, for instance, John Eligon and Patrick Zuo, "Designer Seed Thought To Be Latest Target by Chinese," *New York Times*, February 4, 2014. *http://www.nytimes.com/2014/02/05/us/chinese-implicated-in-agricultural-espionage-efforts.html*.
[91] cf., Richard P. Suttmeier, "State, Self-Organization, and Identity in the Building of Sino-U.S. Cooperation in Science and Technology," *Asian Perspective* 32, 1 (2008): 5-31. See also Anthony Welch and Hao Jie, "How Returnees and Diaspora Contribute to Chinese Higher Education," *China Daily Blog*, July 9, 2013. *http://blog.chinadaily.com.cn/blog-1142759-11055.html*.

cooperate.[92] Assessing the balance of benefits from this ethnically based pattern of cooperation is formidable. These activities have undoubtedly played a large role in helping China in its "catch-up" phase of the last 35 years, but they have also facilitated the flow of talented and Chinese scientists to the United States, thus enriching the U.S. research enterprise.

National Systems and National Interests

The question of whether the rather decentralized approach to S&T engagement with China on the U.S. side hurts or harms U.S. national interests with regard to unlawful or unintended technology transfers, losses of IP, etc., is not readily answered. Many observers in the United States and abroad would argue that the strength of the U.S. research and innovation system is precisely in the freedoms and openness that a highly decentralized system permits. Finding the right modalities to stem the loss of technology and IP, therefore, involves the challenge of finding the right balance between effective national coordination and regulation and an avoidance of over-regulation impeding the flow of original and innovative ideas. As indicated above, China has certainly benefitted from its S&T relationship with the U.S. in its various aspects, becoming in the process a far more capable power in S&T with all that entails for economic competitiveness and national security. In select cases, a more centralized control regime may have prevented transmission of strategic information harmful to U.S. interests, while at the same time preserving U.S. research and innovation capabilities. More broadly, though, the attenuation of strategic information flow would have been unlikely without weakening the relationship itself, or compromising U.S. traditions and best practices.

The national interest implications of the variegated and decentralized U.S. research and innovation systems can also be approached through a somewhat different framing. In this perspective, the question is less one of decentralization facilitating technology leakage than one of decentralization leading to a fragmentation of national purpose and capabilities, which threatens sustained U.S. leadership in research and innovation. In this view, the case can be made for a more vigorous government approach to maintaining U.S. research and innovation excellence in conjunction with renewed partnerships with industry and higher education. This would include strong government leadership in the maintenance of basic research excellence and world-class public universities and, for relations with China, the development of a more coherent strategic approach to capturing value for U.S. interests from engagement with an increasingly capable and well-resourced Chinese research and innovation system.

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[92] For instance, China's Thousand Talents Program introduced in 2008 offers very attractive packages to induce overseas high-level scientific and accomplished entrepreneurial talent to relocate to China on either a full-time or part-time basis. The program is administered by various Chinese entities, including local governments. As administered by the University of the Chinese Academy of Science, which requires that candidates "hold a current professorship in a distinguished international university or an equivalent in international research institution," full-time positions come with a salary comparable to the current overseas salary, a grant of *renminbi* (RMB) 1 to 2 million ($US 160,000-320,000) in research start-up funds, housing, and other benefits, plus an additional one-time RMB 1 million tax-free stipend. Part-time positions, requiring work in China for at least two months each year, carry a stipend of RMB 500,000 and subsidized housing. See University of Chinese Academy of Sciences, "The Long-Term Thousand Talents Program." *http://english.ucas.ac.cn/JoinUs/Pages/default.aspx*. For an assessment of the program's success, see Yojana Sharma, "China's Effort to Recruit Top Academic Talent Faces Hurdles," *The Chronicle of Higher Education*, May 28, 2013. *http://chronicle.com/article/article-content/139485/*.

TRENDS AND RECOMMENDATIONS

This report has documented how the bilateral relationship has evolved over the course of 35 years. A few of the trends we have seen warrant explicit emphasis.

1. The first of these is the growing complexity of the relationship, due to the involvement of industrial, academic, NGO, and people-to-people interactions in S&T, as well as those of the two governments. U.S. policy makers who in 1979 sought to create a "web of relationships" with China certainly succeeded. Relatedly, both sides show a growing interest in combining these various strands into new forms of public-private partnerships. These partnerships often involve commercial interests as both sides seek to exploit scientific knowledge for the purposes of producing useful and profitable innovations. China's interest in greatly enhancing the role of enterprises in its national systems for research and innovation reinforces the tendency to incorporate commercial interests into bilateral S&T activities. We should not be surprised, therefore, that intellectual property issues are likely to loom more prominently in the relationship.

2. Secondly, within the government sector itself we see a variety of new initiatives for S&T cooperation, reflecting both diplomatic and scientific and technological objectives, that stem from high-level bilateral political commitments. These include summit meetings, the workings of the S&ED (including the Innovation Dialogue), and the new people-to-people exchange. In some cases, these fit well with existing agreements under the S&T Agreement, but in others they call for new arrangements.

3. The willingness of the Chinese side to assume a greater share of the costs of the relationship is a third trend. We have seen this willingness manifest itself in support for large facilities, and for covering travel costs for U.S. participants. This trend clearly reflects the increasing commitment China is making to S&T more generally, while budget realities on the U.S. side have led to fewer resources available for managing the relationship. While China sooner or later will have to face limitations on the growth of its own spending, it is clear that a dominant U.S. role in the relationship, based on the achievements, maturity, and administrative acumen of its science and technology system, is not foreordained to continue in the face of robust Chinese commitments.

4. A fourth trend, following the initiation of the international S&T cooperation plan for the 12th Five-Year Plan period, is the growing expansion of China's bilateral and multilateral international science and technology relations. In many cases—in agriculture, health, meteorology and oceanography, environmental protection, and "big science"—the latter overlaps with bilateral relations with the United States and offers new opportunities for cooperation. The United States has long been a leader in many of these multilateral forums, and has increasingly been redefining the technical missions of its agencies to adopt multilateral perspectives in the face of global health, food, energy, safety, climate and environmental protection, and other problems. The strength of U.S. S&T in these areas, and the political commitment to international multilateral action, have been important ingredients in science diplomacy and the projection of U.S. "soft power." As China's wealth and capabilities have increased, it is demonstrating its own interests in multilateral affairs and the operation of multilateral organizations dealing with S&T issues. It is likely that we will see a continuing growth in Chinese commitments to S&T in a multilateral framework (as well as bilaterally) and a growing appreciation that such commitments provide valuable assets for diplomatic initiatives.

5. Finally, national security concerns on both sides have complicated the relationship in a variety of ways. Both sides show increasing concerns over information security, data sharing restrictions, and export control policies, and there are some indications that U.S. concerns over Chinese espionage—largely stemming from arenas other than the S&T Agreement—may be bleeding over into activities under the Agreement.

The identification of these and other trends point to the need for the United States to rethink several areas of its S&T relationship with China. While China's status as an emerging S&T superpower is still debated and questioned by some, there is little doubt that China has become an important player in international S&T, as recognized by scientists, engineers, and policy makers in many countries. The manifest asymmetry in capabilities that once characterized the relationship with the United States has given way to a far more complex pattern of interdependency. Although the U.S. side has responded to these realities in a variety of ways, still more might be done to develop a strategic orientation to its S&T engagement with China, especially with regard to funding and staffing.

Assuming that S&T development in China is a matter of some consequence for U.S. national interests, and assuming further that a strategic engagement with China on these S&T issues is necessary for serving those interests, the quality of that engagement might be better served by:

1. Rethinking and clarifying U.S. objectives for the bilateral S&T relationship in light of twenty-first-century realities, with a focus on the relative importance of diplomatic versus scientific and technological goals.

2. Ensuring that there is adequate funding to support staffing and strategic programmatic initiatives at the OSTP and the agency levels.

3. Considering ways to modernize the Agreement, especially with regard to IPR provisions and to the composition of the JCM. Thought should be given to adding nongovernmental participants to the JCM as members, or perhaps as regular observers. The applicability of the CERC IPR provisions for the Agreement, replacing the current Annex 1, should be explored.

4. Convening annual interagency workshops, which would also involve industry and academic participation, for discussions of trends in Chinese S&T, new opportunities these trends present, and strategies needed to seize these opportunities. Such workshops could be done in support of the planning of JCM and ESM meetings and the preparation of the biennial report to Congress.

5. Enhancing the information infrastructure supporting the relationship by building research and analytic capabilities for tracking Chinese S&T policy developments, and publication and patenting trends, with an eye toward better understanding Chinese strengths and emerging centers of excellence.

The S&T relationship has often reflected a mutually beneficial and trust-enhancing partnership, and continues to do so. Yet its evolution also reflects the complexities wrought by competition and mistrust found in the broader U.S.-China relationship. Despite these complexities and China's increasing wealth and capabilities, China still looks to the United States as a leader of research and innovation and a source for best practices in S&T, a perception which has redounded to strengthened U.S. influence in the relationship.

But in reviewing the U.S.-China S&T relationship in 2014 against the background of its 35-year evolution, one cannot help but wonder whether the United States, by its own actions and inactions, is ceding its long-held leadership position in S&T to a rising China and, in doing so, is thus surrendering the very tools needed to maintain advantage from engagement with China. In spite of China's problems in building its S&T capabilities, its willingness to make major commitments to development is showing results, as recognized by various international observers. The trajectory of Chinese development, and the wealth and capabilities it is generating, provides interesting new challenges and opportunities for the United States after years of facilitating China's science and technology development. Taking advantage of these opportunities and meeting those challenges, however, requires strategy and modest—but serious—public sector investments, which the United States seems unable to generate as a result of self-imposed policy and budgetary disarray.

APPENDIX: U.S.-CHINA CLEAN ENERGY RESEARCH CENTER (CERC) MEMBERS

Advanced Coal Technology

West Virginia University Research Corporation (U.S. leader)
Babcock & Wilcox
Los Alamos National Laboratory
University of Wyoming
Duke Energy
LP Amina
U.S.-China Clean Energy Forum, Washington State China Relations Council
Indiana Geological Survey
National Energy Technology Laboratory
World Resources Institute
Lawrence Livermore National Laboratory
University of Kentucky

Huazhong University of Science and Technology (Chinese leader)
China Huaneng Group Clean Energy Research Institute
China University of Mining and Technology
Research Center for Energy and Power, Chinese Academy of Sciences
China Huaneng Group Power International, Inc.
ENN (XinAo Group)
Shaanxi Yanchang Petroleum (Group)
Harbin Institute of Technology
Shanghai Jiao Tong University
China Power Engineering Consulting Group Corporation (CPECC)
Institute of Rock & Soil Mechanics, Chinese Academy of Sciences
Shenhua Group Corporation
Tsinghua University
China Power Investment Corporation
Northwest University of China
Zhejiang University

Building Energy Efficiency

Lawrence Berkeley National Laboratory (U.S. leader)
Bentley Systems, Inc.
C3 Energy
ClimateMaster
Dow Chemical Company
The Energy Foundation, China Sustainable Energy Program
ICF International
Lutron Electronics
Massachusetts Institute of Technology
Natural Resources Defense Council
Oak Ridge National Laboratory
SAGE Electrochromics

The Center of Science and Technology of Construction, Ministry of Housing and Urban-Rural Development (Chinese leader)
Anhui Roba Energy Saving Technology Co.
Beijing Ever Source Science & Technology Co.
Beijing Huaqing Geothermal Development Co.
Beijing Huayi Leye Energy Service Co.
Beijing Lampower Photoelectric Co.
Beijing Persagy Energy Saving Technology Co.
Beijing Zhongchengke Green Building Technology
China Academy of Building Research
China Lanp Electrical Co.
Chint Solar (Zhejiang) Co.
Chongqing University
Chongqing Zhonghai Industry Co.
CISDI Engineering Co.
CSUS Green Lighting Science & Technology Research Center
Dasheng Roller Shutters (Shanghai) Co.
Dongguan Vanke Building Technology Research Co.
East-West Control Group (Shenyang) Co.
ENN Group Co.
Guangzhou Zhengli General Electric Co.
Himin Solar Energy Group
Jiangsu Aide Solar Energy Technology Co.
Jiangsu Disimai GSHP Air Control Co.
Jiangsu Refrigeration & Heating Saving Equipment Co.
Jiangxi Lattice Lighting Co.
Jilin Kelong Building Energy-Saving Technology Co.
Landsea Group
LH Technology Co.
Liaoning Solar Energy R&D Co.
Nanjing Fullshare Energy Technology Co.
Nari Technology Development Co.
Shanghai Convertergy Energy Technology Co.
Shanghai Fuka Construction & Engineering Co.
Shanghai Futian Air Conditioning Equipment Company Co.
Shanghai Qingying Industrial Shares Co.
Solatube CECIC Daylight Technology Co.
Telchina (Shandong) Co.
Tianjin University
Tongguang Jaingong Construction Group Co.
Tongji University
Tsinghua University
Wuxi Suntech Power Co.

Clean Vehicles

The University of Michigan (U.S. leader)
Aramco Services
Argonne National Laboratory

Delphi
Denso
Eaton
Environmental Protection Agency
Ford Motor Company (Ford)
Honda R&D Americas, Inc.
Joint Bio Energy Institute
Massachusetts Institute of Technology
Oak Ridge National Laboratory, Energy, and Transportation Science
The Ohio State University
PJM Interconnection
Sandia National Laboratories, Combustion Research Facility
TE Connectivity
Toyota Motor Company, Toyota Motor Engineering and Manufacturing North America

Tsinghua University (Chinese leader)
Beihang University
Beijing Institute of Technology
Beijing Keypower
Changzhou ECTEK Automotive Electronics Limited
China Automotive Engineering Research Institute Co.
China Automotive Technology & Research Center
China Potevio
Chinese Academy of Sciences
Geely Group
Hunan University
JAC Motors
Jingjin Electric Co.
North China Electric Power University
SAIC Motor
Shanghai General Motors Wuling
Shanghai Jiao Tong University
Tianjin Lishen Battery Joint-Stock Co.
Tianjin University
Tongji University
Wanxiang
Wuhan University of Technology