

China's S&T Emergence

A Proposal for U.S. DOD-China Collaboration in Fundamental Research

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Introduction

In recent years, China has begun to emerge as a potential contributor of world-class science and technology (S&T) in a number of areas, including energetic materials, nanotechnology, biotechnology, information technology (IT), and materials science. While it is true that China is still developing its S&T base, the high level of investment in science and technology and aggressive push for reform have led the quality of Chinese S&T to rise dramatically in the past decade. In 2006, China surpassed Japan to become the world's second highest research and development (R&D) investor.

Recognizing the potential for China to become a world leader in some key areas of science and technology, it is important to develop an S&T collaborative relationship with China in fundamental research so that we can identify and capitalize on emerging trends and technologies and leverage foreign resources and capabilities in both the short and long term that are of benefit to the U.S. Department of Defense (DOD). Research collaborations would involve DOD scientists and the Chinese academic community doing unclassified fundamental research.¹ Fundamental research, which is the focus of this report, is defined in National Security Decision Directive (NSDD) 189 as follows:

“Fundamental research” means basic and applied research in science and engineering, the results of which ordinarily are published and shared broadly within the scientific community, as distinguished from proprietary research and from industrial development, design, production and product utilization, the results of which ordinarily are restricted for proprietary or national security reasons.²

Engaging in collaborative fundamental research with China, therefore, will not contravene the activities considered inappropriate by the National Defense Authorization Act (NDAA) of 2000 and will not have military implications. Further, fundamental research does not fall under the International Traffic in Arms Regulations (ITAR) or Export Administration Regulations (EAR) as it does not relate to any sale, transfer, or proposal to sell or transfer defense articles or defense services.

This report proposes the establishment of a constructive, phased strategy for engaging in collaborative fundamental research with Chinese academic institutions. Recent evaluations of top S&T universities and their specific capabilities suggest appropriate scientific areas such as materials science, ocean science, nanoscience, energetics sciences, energy, and biotechnology, where beneficial collaborations between DOD and China should be fostered.

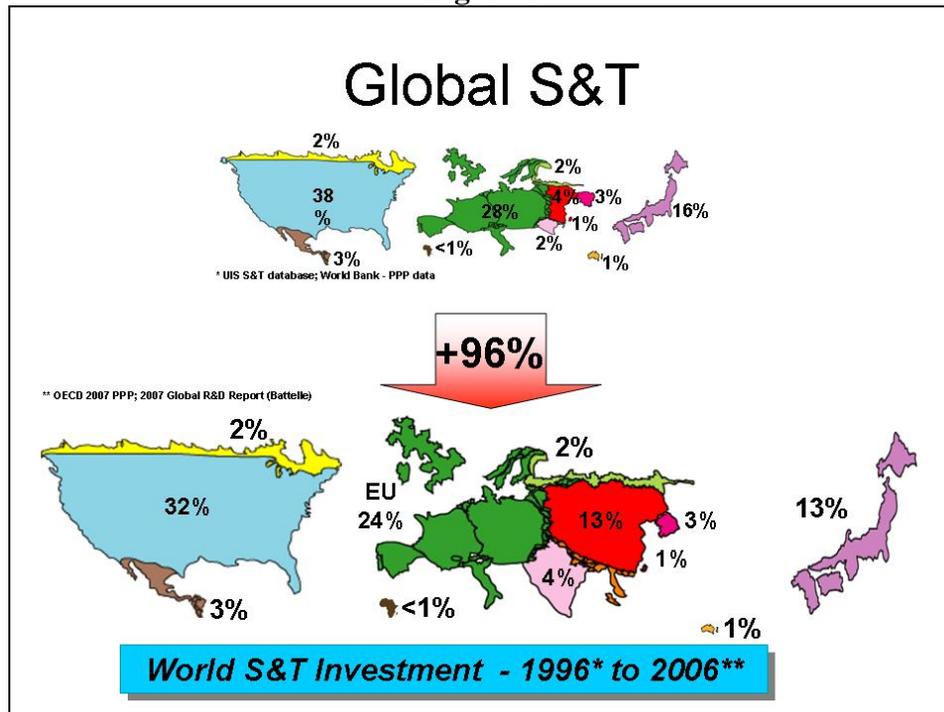
¹ The authors of this report recognize that the Hong Kong Policy Act of 1992 establishes the authority of the U.S. Government to treat Hong Kong (Special Administrative Region) as a non-sovereign entity distinct from China. However, for the purposes of this paper, we use the term China to encompass both mainland China and Hong Kong.

² NSDD-189, “White House Directive on Fundamental Research,” September 21, 1985, available at <<http://www.aau.edu/research/ITAR-NSDD189.html>>.

Science and Technology in China

While the United States will undoubtedly remain an S&T powerhouse for many years to come, a number of other countries are rapidly becoming strong centers for science and innovation and the generation of new ideas. A recent report by the U.S. National Science Foundation points out the rise of S&T capability in Asia.³ Within Asia, China is rapidly becoming a major player in S&T. China's technological rise can be measured not only by inputs (S&T funding and S&T staffing), but also by outputs (scientific publications, patents, and collaborations) as reported by diverse sources.⁴ Figure 1 makes the point rather dramatically that in terms of the world's investment in S&T over the past 10 years (a rise of 96 percent in terms of purchasing power parity), China's growth has dwarfed that of all the other countries shown. Also noteworthy is the drop in relative worldwide investment in S&T by the United States (6 percent) and the European Union (4 percent) during this same period (1996–2006). The ambitious and sustained rise in S&T in China is discussed in detail below.

Figure 1



³ National Science Foundation, Division of Science Resources Statistics, "Asia's Rising Science and Technology Strength: Comparative Indicators for Asia, the European Union and the United States," NSF 07-319, August 2007, available at http://www.nsf.gov/statistics/nsf07319/.

⁴ Terence Lyons et al, "The Changing Research Landscape: The Rise of China," *IUMRS Facets*, July 2006; James Keeley and James Wilsdon, "China: The Next Science Superpower?" (London: Demos, January 2007), available at http://www.demos.co.uk/publications/atlaschina; Carl J. Dahlman, "China and India: Emerging Technological Powers," *Issues in Science and Technology*, XXIII, no. 3, Spring 2007; "A Special Report on Technology in India and China: Running Fast," *The Economist*, November 8, 2007, available at http://www.economist.com/specialreports/displaystory.cfm?story_id=10053169.

S&T Reform in China Since 1949

Famous for inventing gunpowder, fireworks, porcelain, and papermaking, China has a rich and long history of technological innovation that spans thousands of years. More recently, China's drive toward S&T modernization began with the founding of the Peoples Republic of China (PRC) in 1949 and the adoption of the Soviet approach to S&T, "characterized by a centralized, top-down system, where government funded institutions dominated R&D."⁵ The PRC also received economic, scientific, and technical assistance from the Soviet Union.

To structure S&T development in China, the government implemented a series of development plans aimed at guiding and modernizing the country's S&T capabilities. The first two plans were the *Long-Term Science and Technology Development Plan from 1956-1967* and the *Science and Technology Development Plan from 1963-1972*.⁶ These plans identified key research topics and goals upon which the country would focus its funding and reform efforts. The *Long-Term Science and Technology Development Plan from 1956-1967*, for example, identified key research areas of computers, semiconductors, automation, electronics, missiles, and nuclear weapons research.⁷

Efforts to modernize its S&T base were greatly hampered during the "Great Proletarian Cultural Revolution" of 1966–1976. This period saw mass upheaval in the country, with Chairman Mao Zedong forcibly removing many Communist Party members from leadership positions and university education being put on hold by thousands of students and professors who were driven into the countryside as a form of reeducation. Science and technology progress suffered greatly, and the S&T gap between China and Western countries widened.⁸

In 1978, the Chinese government held a state S&T Conference, acknowledging that S&T was instrumental to increased productivity and development. Subsequently, Deng Xiaoping announced the new "Open Door" policy and numerous reforms in both industrial and government sectors, leading to "greater interaction between researchers and industry as well as between domestic and foreign industry."⁹ These initiatives revitalized the S&T community and led to implementation of plans including the *National Medium and Long-Term Science and Technology Development Program* and the *Eighth Five-Year-Plan of National Basic Research and Applied Research*. These plans aimed to improve China's competitiveness by the 21st century. They emphasized the importance of basic research in S&T development and ultimately led to the

⁵ Kathleen Walsh, "Soaring Eagle, Flying Dragon: Industrial R&D and Innovation in the United States and China," *Proceedings of the China-U.S. Forum on Science and Technology: Section III – Background Papers*, October 2006, 227, available at <<http://www.law.gmu.edu/nctl/stpp/pubs/SectionIII.pdf>>.

⁶ Liu Yun, Duan Yibing, Xiao Guangling, Yang Yu and Tang Le, "Basic Research: A Comparison of the United States and China," *Proceedings of the China-U.S. Forum on Science and Technology: Section III – Background Papers*, October 2006, 234, available at <<http://www.law.gmu.edu/nctl/stpp/pubs/SectionIII.pdf>>. Note: The titles of the two plans vary in the academic literature.

⁷ *Ibid.*, 244.

⁸ *Ibid.*, 245.

⁹ Walsh, 227.

implementation of the *National Key Basic Research Development Plan*, also known as the “973 Plan,” which promoted basic research through government-funded projects.¹⁰ The current stage in China’s rapid S&T modernization drive can be termed *National Innovation System Development*.¹¹ Beginning in 1998, this period has seen a number of national plans with a strong focus on innovation, high-tech industry, and international collaboration.

According to the Department of State, the driving forces behind China’s S&T advances have been market-based reforms of China’s S&T infrastructure; the large supply of domestic S&T research talent; foreign capital investment from multinational companies; technology transfer from foreign companies; and Chinese government investment in strategic high-tech technologies.¹²

China has promoted the commercialization of technology and inventions, fostered domestic entrepreneurship and foreign investment in China, encouraged cooperation between industry, universities and national institutes, and established numerous high-tech industrial parks. Further, the government has increased funding in S&T education and actively recruited Chinese scientists and engineers trained in foreign universities, offering them higher salaries, large research budgets and state-of-the-art resources to return to China to work in national S&T centers. These efforts led to the creation of the most recent plan for S&T modernization.

Issued in February 2006, the *National Guideline on Medium and Long-Term Program for Science and Technology Development (2006-2020)* sets out China’s S&T goals for the next 13 years. The goal of the plan is to “make China a globally preeminent scientific, technological, and economic power, to become less reliant on foreign technology and instead to create independent, indigenous innovation.”¹³

The plan describes numerous subject areas in which to focus S&T research. In particular, it lists 11 key fields, with 68 priority subject areas in those fields. The 11 fields include: energy, water and mineral resources, environment, agriculture, manufacturing industry, transportation sector, IT and modern service industries, population and health, urbanization and urban development, public safety, and national defense.

The plan also lists eight categories of important, cutting-edge technologies, including: biotechnology, IT, new materials, advanced manufacturing, advanced energy, marine, laser, and aerospace technologies. Within these technologies, the plan discusses animal and plant sciences, drug molecular design technologies, protein engineering, high-

¹⁰ Liu Yun et al., 245.

¹¹ Walsh, 221, 227.

¹² U.S. Department of State, “U.S. China Science and Technology Cooperation (S&T Agreement): Report to Congress,” April 15, 2005, available at <<http://state.gov/g/oes/rls/or/44681.htm>>.

¹³ American Electronics Association, “China’s 15 Year Science and Technology Plan: What Does it Mean to Spawn ‘Indigenous Innovation’?” *The AeA Competitiveness Series*, Vol. 14, April 2007.

temperature superconducting technologies, hydrogen energy and fuel cell technologies, natural gas hydrate development technologies, and brain and cognitive sciences.¹⁴

To make China a world leader in S&T, the plan aims for an R&D expenditure of 2.5 percent of gross domestic product (GDP) by 2020 and the reduction of Chinese reliance on foreign technology to 30 percent or below. The guiding purpose of the plan is to improve independent innovation in industry, academia, and research institutes through, among other activities, creating a national innovation system. China states the goals of becoming an innovation-oriented country by 2020, ranking fifth in the world in terms of the number of patents awarded to nationals by 2020, and becoming a world leader in S&T by 2050.¹⁵ Since 2000, Chinese applications for invention patents have grown 23 percent annually.¹⁶

In the *National Guideline on Medium and Long-Term Program for Science and Technology Development (2006-2020)*, China addresses intellectual property rights (IPR) issues that have been a major impediment to conducting business in China. The plan will expedite the implementation of a national IPR strategy, implement a technological standards strategy, and crack down on infringement of IPR:

China needs to protect intellectual property rights and safeguard the interests of rights holders not only to perfect the market economic structure and promote independent innovation but also to establish its international credibility and carry out cooperation with other countries. We must further perfect the national system of intellectual property rights, foster a legal environment of respecting and protecting intellectual property rights, promote greater awareness of intellectual property rights in the whole of society and higher standards of management for intellectual property rights in the country, increase the protection of intellectual property rights, and severely crack down on various infringements of intellectual property rights in accordance with the law.¹⁷

State of the Art in China

As previously mentioned, to achieve its goal of an S&T powerhouse by 2050, China has instituted aggressive reforms throughout nearly every sector of its S&T base. This drive towards modernization was one of the factors that led to China's accession to the World Trade Organization (WTO) on December 11, 2001, an objective the country had been pursuing since 1986, when it applied for admission to the WTO's predecessor, the General Agreement on Tariffs and Trade (GATT).¹⁸

¹⁴ People's Republic of China, "Guidelines for the Medium-and Long-Term National Science and Technology Development Program (2006-2020)," February 9, 2006.

¹⁵ Embassy of the People's Republic of China in the United States of America, "China issues guidelines on sci-tech development program," February 9, 2006, available at <<http://www.china-embassy.org/eng/gyzg/t234559.htm>>.

¹⁶ James Keeley and James Wilsdon, "China: The Next Science Superpower?" January 2007, available at <<http://www.demos.co.uk/publications/atlaschina>>.

¹⁷ People's Republic of China, "Guidelines for the Medium-and Long-Term National Science and Technology Development Program (2006-2020)," February 9, 2006.

¹⁸ Office of the U.S. Trade Representative, "Background Information on China's Accession to the World Trade Organization," December 11, 2001, available at <http://www.ustr.gov/Document_Library/Fact_Sheets/2001/Background_Information_on_China's_Accession_to_the_World_Trade_Organization.html>.

Total R&D expenditures have risen from roughly 0.6 percent of GDP in 1995 to 1.5 percent in 2005, with total R&D in 2006 equaling about \$139 billion.¹⁹ Every year since 1999, China's spending on R&D has increased by more than 20 percent, and in 2006 the Organization for Economic Cooperation and Development announced that China had surpassed Japan to become the world's second highest R&D investor. The United States ranks first.²⁰

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Japan to become the
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Some of the key areas China has been funneling research money into include energetic materials, nanotechnology, biotechnology, IT, and materials science. In 2005, for example, China's biotech market was estimated at roughly \$3 billion and is forecast to reach \$9 billion in 2010. The Chinese

government spends between \$500-600 million per year on biotechnology through research institutes and academic centers, and has already seen results from its investment.²¹

Industry

Hundreds of multinational companies already collaborate with China, operating R&D centers in 53 state-of-the-art, high-tech industrial parks located throughout the country, including in Beijing, Chengdu, Shanghai, Shenzhen, and Wuhan. By the end of 2005, the Chinese Ministry of Commerce had estimated that 750 multinational R&D centers were operational in China,²² including a number of American companies, such as AspenTech, DesignRx Pharmaceuticals, Honeywell, General Motors, Aurora Systems, Integrated Silicon Solution, Inc., Microsoft, and IBM.

IBM, which opened its first research laboratory in China in September 1995, operates a laboratory in Beijing that employs over 150 technical staff members.²³ Honeywell, another American company, first opened an office in Beijing in 1983 and now employs over 4,000 people in 12 cities throughout the country, conducting research on specialty materials, auto control systems, and transportation systems.²⁴ Degussa, a German chemical company, operates a 100-person R&D facility in Shanghai, and DuPont operates a large facility in Shanghai in the Zhangjiang Hi-Tech Park with plans to expand to 400 R&D personnel.²⁵ General Motors, which already has a 1,300-employee research center in Shanghai in partnership with the Shanghai Automotive Industry Corporation,

¹⁹ Adam Segal, "The Competitiveness of Chinese R&D," June 27, 2007, Notes Prepared for Asian Science & Technology Forum, Washington, DC.

²⁰ James Keeley and James Wilsdon, "China: The Next Science Superpower?" January 2007, available at <<http://www.demos.co.uk/publications/atlaschina>>.

²¹ U.S. Department of State, "U.S. China Science and Technology Cooperation (S&T Agreement): Report to Congress," April 15, 2005, available at <<http://state.gov/g/oes/rls/or/44681.htm>>.

²² Ibid.

²³ IBM, "China Research Laboratory," available at <<http://researchweb.watson.ibm.com/beijing/index.html>>.

²⁴ Honeywell, "History in China," available at <<http://www.honeywell.com/sites/portal?smap=china&page=historyinchina&theme=T8&c=n>>.

²⁵ Jean-Francois Tremblay, "R&D Takes Off in Shanghai." *Chemical and Engineering News*, 84, no. 34, August 21, 2006, available at <<http://pubs.acs.org/cen/coverstory/84/8434shanghai.html>>.

announced in late October 2007 that it would open a separate, wholly owned research center in Shanghai to develop electric vehicle technologies, including hybrids and fuel cells.²⁶

Academia

China's push for higher education also has seen success. In 2004, China employed 2.25 million scientists and engineers and published 6.52 percent of the world's scientific publications, up from 2.05 percent in 1995. More than 6.5 million students were enrolled in undergraduate science, medicine and engineering programs in 2004, and more than half a million in postgraduate science, medicine and engineering programs; 23,500 doctorates were awarded, 70 percent of them in science-related subjects.²⁷ In 2007, nearly three million scientists and engineers will graduate from Chinese universities.²⁸

In 2007, nearly three million scientists and engineers will graduate from Chinese universities

In 2006, five Chinese universities ranked in the global top 100 universities for science: Peking University,²⁹ China University of Science and Technology, Tsinghua University, Fudan University, and Nanjing University.³⁰ Other leading S&T universities identified by DOD scientists who have

participated in site visits include Zhejiang University, the Ocean University of China, and the Hong Kong University of Science and Technology. Below we provide a brief overview of some of the scientific areas where we believe DOD would benefit in a significant way from collaborations with Chinese scientists. This list is not comprehensive.

In 2006, Peking University was ranked 12th in the world for science. Some potential areas of collaborative basic research between DOD scientists and Peking University scientists include BioMEMS (biochips for protein microarray and cell chip application), computational simulation on charge transport of semiconductor and related modeling areas, and silicon based technology development. A particularly novel research program linking carbon nanotubes with more traditional silicon substrate electronics may lead to totally new kinds of electronic devices with wide potential applications.

The Ocean University of China (OUC) in Qingdao is regarded internationally as the premier university in China for research in ocean sciences. Strong programs of fundamental research at OUC are in marine chemistry, ocean currents, and remote sensing. OUC has developed cooperative programs with institutions in more than 20 countries, including the United States. Scientists from the University of Delaware, supported by the United States Office of Naval Research, the National Aeronautics and

²⁶ Keith Bradsher, "G.M. Will Build Its Own Research Center in China," *New York Times*, October 30, 2007, available at <<http://www.nytimes.com/2007/10/30/business/30auto.html>>.

²⁷ James Keeley and James Wilsdon, "China: The Next Science Superpower?" January 2007, available at <<http://www.demos.co.uk/publications/atlaschina>>.

²⁸ Asian Technology Information Program, "Survey of Chinese S&T Status," June 20, 2007.

²⁹ Peking University, established in 1898, is China's first national university.

³⁰ Ibid.

Space Administration, and the National Oceanographic and Atmospheric Administration, working in collaboration with OUC scientists, recently developed a technique for using satellite sensors to detect disturbances in deep ocean currents.³¹

The University of Science and Technology of China has recently begun major research programs in the areas of nanotechnology, quantum information science, life sciences, safety engineering and technology, synchrotron radiation, and space science. Tsinghua University, which is often referred to as the “MIT of China,” is becoming well known for optoelectronics research, hardware and software development for communications, and nanotechnology.

Major scientific areas of focus at the Dalian Institute of Chemical Physics in which we should have significant interest include molecular dynamics, energy, and biotechnology. The Institute is also among the best in the world in velocity map imaging detection methods and has strong research programs in catalysis, materials, proteomics, and alternative energy.

Two other top Chinese universities on the mainland that have expressed interest in engaging with DOD basic research organizations include Fudan University in Shanghai and Zhejiang University in Hangzhou. Fudan is very strong in biology, mathematics and physics. The physics department is in the top five in China and has recruited many young faculty who received their doctorates in Europe, Canada or the United States. They have strong research programs in interdisciplinary approaches to materials science, computational physics, spintronics, photonics and superconductivity.

Zhejiang University is the top ranked university in Mainland China for photonics research and also has strong programs in meta-materials, optics and electromagnetics.

The Hong Kong University of Science and Technology is very strong in innovative basic science. Even though the school has only been in operation for just under 17 years, it is a leading Chinese university in nanomaterials and nanofabrication, biotechnology, IT, and electronics, and has a very strong innovative and entrepreneurial focus. An innovative research program exploring the active components of herbs used in traditional Chinese medicine and their usefulness in improving human neurocognitive performance is underway and growing rapidly.

It is also important to mention the strong S&T collaborative relationships that already exist between American and Chinese universities. In November 2005, for example, the National Science Foundation awarded the University of California Santa Barbara (UCSB) a \$1.5 million grant to establish a research and education partnership with the Dalian Institute of Chemical Physics of the Chinese Academy of Sciences in chemistry, physics, materials science, and chemical engineering.³² Further, many of the leaders of the top

³¹ University of Delaware, “Scientists Use Satellites to Detect Deep-Ocean Whirlpools,” March 21, 2006, available at <<http://www.sciencedaily.com/releases/2006/03/060320223213.htm>>.

³² University of California, Santa Barbara, “UCSB Awarded \$1.5-Million for Research and Training Partnership with China,” November 29, 2005, available at <<http://www.ia.ucsb.edu/pa/>>

university S&T programs in China were recruited from and still have affiliations with active laboratories in top U.S. universities.

The push for academic reform in China is encouraging and adds credibility to China's drive to become a world class S&T power. As China invests more capital in its domestic S&T infrastructure, the likelihood of innovative breakthroughs in fundamental research increases, as do opportunities for beneficial S&T collaboration between the DOD S&T community and China's academic community.

Impediments to Cooperation

Even though the quality of Chinese S&T has risen in recent years and is expected to rise even more rapidly due to current plans by the Chinese government to significantly increase investment in basic scientific research and education, a number of issues continue to cause some concern. Most of these issues, however, including transparency, product quality, and regulatory standards, are common among countries rapidly developing their S&T capabilities and China is making some attempts to address these issues.

One of the most widely discussed concerns with Chinese S&T cooperation relates to weak intellectual property rights and weak enforcement of those rights. However, it can be argued that China has made improvements in IPR in recent years. "There are many indications that, over the past 20 years, Beijing has been intent on having a good, enforceable IP system. It took 30–40 years for Japan, Korea and Taiwan to get to the same point. China, contrary to popular perception, has made good progress."³³ As mentioned previously, in its *National Guideline on Medium and Long-Term Program for Science and Technology Development (2006-2020)*, the Chinese government acknowledges the issue of IPR and states that it plans to expedite the implementation of a national strategy on IPR, implement a technological standards strategy, and crack down on infringement of IPR.

Moving Forward

Overall, the quality of academic research in China is improving at a very fast pace. DOD has much to gain from collaborating with the Chinese academic community and we should encourage engagement in mutually beneficial scientific collaboration. Now is the time to pursue a policy of active engagement.

display.aspx?pk=1381>.

³³ Ian Harvey, "The West Must Heed China's Rise in the Global Patent Race," *Financial Times*, September 21, 2005, available at <<http://www.ft.com/cms/s/fc6e0eca-2a3d-11da-b890-00000e2511c8.html>>.

History of U.S.-China S&T Collaboration

1979 S&T Agreement

In 1979, President Carter and Premier Deng Xiaoping signed the U.S.-China Agreement on Cooperation in Science and Technology (hereafter referred to as 1979 S&T Agreement). One of the longest-standing U.S.-China accords, the 1979 S&T Agreement has been broadly endorsed by numerous Federal agencies through their participation in cooperative exchanges and activities with China, on topics ranging from fisheries, earth and atmospheric sciences, agriculture, environmental science, climate change, geology, disaster research, civilian industrial technology, and health, as well as basic research in chemistry, and physics.³⁴ DOD does not participate in the Agreement.

On April 18, 2006, in recognition of the benefits to both countries from engaging in a long-term bilateral S&T agreement, the United States and China signed a protocol extending the bilateral S&T Cooperation Agreement until 2011. “The extension enables the continuation of the ongoing exchange of S&T knowledge, the pursuit of advanced and applied scientific and technical projects, and the augmentation of S&T capabilities.”³⁵ Among areas for continued and potential future research are basic research in physics, chemistry, and agriculture. Because the 1979 S&T Agreement is a broad umbrella agreement, U.S. agencies and their Chinese counterparts develop subsidiary, subject-specific protocols and memorandums of understanding (MOUs) for cooperation.³⁶ As of 2006, there were more than 26 active protocols and over 60 annexes under the agreement.

U.S. Government agencies actively engaged in collaborative S&T activities with China under the 1979 S&T Agreement include the Department of Energy (DOE), the Department of Health and Human Services (in particular the National Institutes of Health), and the National Science Foundation. Through briefly looking at the types of S&T collaboration these agencies are involved in, we can gain a better understanding of the U.S.-China S&T relationship.

Department of Energy

Since 1979, DOE has participated in a number of bilateral agreements with China for the purpose of advancing research and development in high-energy physics, nuclear fusion, energy efficiency, and nuclear security technology. Some of the protocols and accords DOE and China currently collaborate in are:

- High Energy Physics Implementing Accord. This bilateral accord between the DOE and China’s Ministry of Science and Technology and the Chinese Academy

³⁴ U.S. Department of State, “U.S. China Science and Technology Cooperation (S&T Agreement): Report to Congress,” December 30, 2006, available at <<http://www.state.gov/g/oes/rls/or/2006/96328.htm>>.

³⁵ U.S. Department of State, “United States and the People’s Republic of China Renew Science and Technology Cooperation Agreement,” April 18, 2006, available at <<http://www.state.gov/r/pa/prs/ps/2006/64699.htm>>.

³⁶ U.S. Department of State, “U.S. China Science and Technology Cooperation (S&T Agreement): Report to Congress,” December 30, 2006, available at <<http://www.state.gov/g/oes/rls/or/2006/96328.htm>>.

of Sciences was originally signed in 1979. The accord is focused on advancing theoretical and experimental research, accelerator design, and related technology.

- Protocol on Nuclear Physics and Controlled Magnetic Fusion. Also signed in 1979, the protocol focuses on plasma physics, fusion technology, advanced design studies, and materials research. The protocol was renewed in April 2006 by DOE and China's Ministry of Science and Technology (MOST).³⁷

On June 30, 2005, the Department of Energy announced the establishment of a DOE office in China. The office, which is located in the U.S. Embassy in Beijing, supports DOE's cooperative efforts with China in energy and nuclear security. According to Secretary of Energy Bodman, "Through the U.S.-China Energy Policy Dialogue, and with on-site assistance from the new DOE office, we can enhance our cooperation to promote energy efficiency, diversify our energy supplies, expand the use of clean energy technologies, as well as continue our mutual efforts to increase nuclear security in both our nations."³⁸

Department of Health and Human Services

The U.S. Department of Health and Human Services (HHS) and the Chinese Ministry of Health have engaged in cooperative activities since 1979 through a variety of protocols in disease control and prevention, public health, biomedical research, health services and health policy research, and health administration and finance. In Fiscal Year 2004 alone, HHS funded 469 Chinese scientists in the visiting program at HHS and supported seven full-time staff members in Beijing.³⁹

The Centers for Disease Control and Prevention (CDC), the Food and Drug Administration (FDA), and the National Institutes of Health (NIH) also participate under the auspices of HHS. In particular, NIH has participated since 1983 under an agreement with the Chinese Academy of Sciences (CAS) for cooperation in basic biomedical sciences. U.S. and Chinese researchers have received funding to collaborate on topics including HIV/AIDS, cancer, hepatitis B, mental health issues, influenza surveillance, and traditional Chinese and herbal medicine.⁴⁰

National Science Foundation

The National Science Foundation (NSF) participates through two main protocols, the "Basic Sciences Protocol" and the "Earthquake Studies Protocol," both of which were signed in 1980. The "Basic Sciences Protocol" includes numerous joint projects in basic research, on topics such as chemistry, IT, water pollution, physics, technology

³⁷ U.S. Department of Energy, "U.S.-China Energy Cooperation," May 22, 2007, available at <<http://www.energy.gov/print/5080.htm>>.

³⁸ U.S. Department of Energy, "Energy Department Opens Office in Beijing," June 30, 2005, available at <<http://usinfo.state.gov/eap/Archive/2005/Jul/01-4937.html>>.

³⁹ U.S. Department of State, "U.S. China Science and Technology Cooperation (S&T Agreement): Report to Congress, United States Department of Health and Human Services," December 30, 2006, available at <<http://www.state.gov/documents/organization/96444.pdf>>

⁴⁰ Ibid.

management, materials science, robotics, and software development.⁴¹ The NSF also indirectly funds research in China through grants to U.S. scientists working with Chinese collaborators.

On May 24, 2006, to facilitate and strengthen collaboration between U.S. and Chinese scientists and engineers, the NSF opened a research operations office in Beijing. During the opening ceremony of the new office, U.S. Ambassador to China Clark Randt discussed the importance of collaboration with China:

With China's increasing importance as a world science and technology player, it is vital for the United States to sustain interactions with international counterparts and specifically with China's rapidly growing science sector...The NSF Beijing Office gives the United States a better opportunity to work jointly to seek science-driven solutions to common problems for the benefit of the globe.⁴²

The NSF Beijing office analyzes S&T developments and policies in China for the U.S. research community and U.S. policymakers. Staff liaises with Chinese S&T agencies and institutions to promote U.S. interests in cooperative science and engineering research and policy formulation.⁴³

Implications of 1979 S&T Agreement

There have been some concerns over S&T collaboration with China and the potential that collaborative activity might contribute to the development of Chinese military capabilities. In its 2006 Report to Congress, the State Department addresses these concerns over technology transfer by stating that they found no direct evidence that activities under the 1979 S&T Agreement contributed to the development of China's military.

State has found no direct evidence that cooperative exchanges and activities under the S&T Agreement has contributed to the transfer of technology and development of China's military. State's analysis has also found no area in which China's acquisition of militarily-useful technologies or information can be attributed with any degree of certainty to cooperative S&T activities under the Agreement.⁴⁴

The report also discusses the benefits to both countries from U.S.-China S&T collaboration. In particular, the report discusses the stabilizing and moderating influence the 1979 S&T Agreement has provided for both countries. Through continuous scientist-to-scientist cooperation since 1979, the agreement has provided an avenue for dialogue

⁴¹ U.S. Department of State, "U.S. China Science and Technology Cooperation (S&T Agreement): Report to Congress, National Science Foundation," December 30, 2006, available at <<http://www.state.gov/documents/organization/96447.pdf>>.

⁴² National Science Foundation, "Press Release," May 24, 2006, available at <<http://www.nsfbeijing.cn/news060608.html>>.

⁴³ U.S. Department of State, "U.S. China Science and Technology Cooperation (S&T Agreement): Report to Congress, National Sciences Foundation," December 30, 2006, available at <<http://www.state.gov/documents/organization/96447.pdf>>.

⁴⁴ U.S. Department of State, "U.S. China Science and Technology Cooperation (S&T Agreement): Report to Congress," December 30, 2006, available at <<http://www.state.gov/g/oes/rls/or/2006/96328.htm>>.

between both countries, regardless of different political situations and tensions that have arisen in the past three decades.⁴⁵ (See sidebar on Analogy: U.S.-Soviet Cooperation in S&T).

China's developing science and technology capabilities suggest that future U.S.-China cooperative activities could yield more benefits to the U.S. than ever before

U.S.-China S&T collaboration also has assisted Chinese domestic policy reforms by providing China with information and expertise that has guided the ongoing reform process. The reform process has been further influenced by the large number of U.S.-educated Chinese scientists who have held and currently hold senior leadership positions in China.

In our estimation, China's large reservoir of U.S.-educated scientists is a positive factor in promoting greater openness in dealing with the U.S. among China's governing and other senior sectors. This has led toward greater engagement across the full spectrum of scientific disciplines, particularly in activities initiated under the 1979 S&T Agreement.⁴⁶

As discussed in the 2006 Report to Congress, scientific cooperation in fundamental basic research between the United States and China provides benefits to both countries, suggesting that there also would be positive benefits from DOD-China collaboration between scientists in fundamental basic research.

As China progresses toward catching up with Western industrialized nations, continued U.S.-China research cooperation allows the U.S. to monitor China's technological advancements. But U.S.-China cooperation can also help leverage U.S. research investments in key high-tech areas by using the contributions of each country to advance the research. China's developing science and technology capabilities suggest that future U.S.-China cooperative activities could yield more benefits to the U.S. than ever before.⁴⁷

⁴⁵ Ibid.

⁴⁶ U.S. Department of State, "U.S. China Science and Technology Cooperation (S&T Agreement): Report to Congress," April 15, 2005, available at <<http://state.gov/g/oes/rls/or/44681.htm>>.

⁴⁷ U.S. Department of State, "U.S. China Science and Technology Cooperation (S&T Agreement): Report to Congress," December 30, 2006, available at <<http://www.state.gov/g/oes/rls/or/2006/96328.htm>>.

Analogy: U.S.-Soviet Cooperation in S&T

It is illustrative when thinking about engagement with China to briefly examine the case of U.S. engagement in fundamental research with the Soviet Union during the Cold War. Despite the ups and downs of the U.S.-U.S.S.R political relationship, S&T collaborations provided long-lasting benefits to both countries. Parallels in engagement with China can be drawn.

Collaboration between the United States and the Soviet Union in S&T officially began on January 27, 1958 with the signing of the “Agreement between the Union of Soviet Socialist Republics and the United States of America on Exchanges on the Cultural, Technical and Educational Fields.” The Agreement, which covered issues as diverse as exchanges of radio and television broadcasts to the development of tourism, also had a strong emphasis on reciprocal visits between scientists. In particular, it discussed industry, agriculture, and health sciences as focal areas for scientific and technical cooperation. The collaborative relationship between the two countries quickly expanded in the wake of the 1958 agreement, with 11 separate bilateral agreements signed in the 1970s.

The relationship took a downturn, however, with the Soviet invasion of Afghanistan in 1979 and imposition of martial law in Poland in 1981, and did not gain momentum again until 1984 when President Ronald Reagan called for the renegotiation of the general S&T exchanges agreement and a reinvigoration of the bilateral S&T agreements. This era saw much controversy over engagement, leading to numerous studies and reports on the impact of the collaborative engagement on national security. Critics of engagement argued that the Soviet Union was using the S&T relationship to gain a technological edge in military science. Such critics argued that the transfer of technology to the U.S.S.R necessitated a U.S. policy of scientific isolation for the Soviet Union. On the opposite side, proponents of engagement argued that because of the nature of fundamental research – unclassified, publishable material – the benefits of engagement far outweighed the negativities. A report issued by the National Academies in 1982 addressed these issues. Among its findings, the report stated that there had been a substantial transfer of technology—much of it directly relevant to military systems—from the United States to the Soviet Union through diverse channels. The report also stated, however, that the imposition of controls could slow the rate of scientific advance and reduce the rate of U.S. technological innovation. In summary, the report concluded that, as a national policy, “security by accomplishment” had much to recommend it over a policy of “security by secrecy.”

According to John Negroponte, then Assistant Secretary for Oceans, International Environmental and Scientific Affairs: “The stakes for science and technology leadership in the modern world are simply too high for us to ignore cooperative opportunities with the Soviet Union. The U.S.S.R. maintains the largest pool of scientists and engineers in the world, including many whose accomplishments are at the forefront of such fields as mathematics and theoretical physics. More importantly, we cannot forget that we are dealing with a closed society, and that these exchanges often give us the only access to significant circles in that society with whom we would otherwise have little or no contact. It would be short-sighted of us not to recognize that it is in our national interest to seek to expand scientific cooperation with the Soviet Union. We have gained much from this relationship already.”

Throughout the relationship, DOD scientists engaged in fundamental research traveled to the Soviet Union, attended conferences and workshops, and participated in site visits.

Sources: “Agreement Between the Union of Soviet Socialist Republics and the United States of America on Exchanges on the Cultural, Technical and Educational Fields,” January 27, 1958, available at <http://untreaty.un.org/unts/1_60000/9/3/00016149.pdf>; John D. Negroponte, “Science and technology exchanges with the Soviet Union.” Statement to Subcommittee on International Scientific Cooperation of the House Committee on Science, Space and Technology, June 25, 1987; Glenn E. Schweitzer, *Scientists, Engineers, and Track-Two Diplomacy: A Half Century of U.S.-Russian Interacademy Cooperation* (Washington, 2004).

U.S. DOD S&T Collaboration with China

DOD Policy on China

Current policy guiding DOD S&T interactions with China can be found in NDAA 2000 which states that the Secretary of Defense may not authorize any military-to-military exchange or contact to be conducted by the armed forces with representatives of the People's Liberation Army if that exchange or contact would create a national security risk. Included in NDAA 2000 are military exchanges and contacts that include inappropriate exposure to any of the following:⁴⁸

1. Force projection operations
2. Nuclear operations
3. Advanced combined-arms and joint combat operations
4. Advanced logistical operations
5. Chemical and biological defense and other capabilities related to weapons of mass destruction
6. Surveillance and reconnaissance operations
7. Joint warfighting experiments and other activities related to a transformation in warfare
8. Military space operations
9. Other advanced capabilities of the Armed Forces
10. Arms sales or military-related technology transfers
11. Release of classified or restricted information
12. Access to a Department of Defense laboratory

Within the DOD S&T community, there are seven categories of research, development, test, and evaluation that run the gamut from fundamental research, which includes basic and early aspects of applied research, to full blown operational system development.

Fundamental research, which is the focus of this report, is basic and applied research in science and engineering, the results of which ordinarily are published and shared broadly within the scientific community, as distinguished from proprietary research and from industrial development, design, production, and product utilization, the results of which ordinarily are restricted for proprietary or national security reasons.⁴⁹ DOD defines basic research as the systematic study directed toward greater knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications in mind. It is unclassified research that can be shared broadly within the scientific community and does not contain specific applications, technology, or product development.⁵⁰ Engaging in collaborative fundamental research with China, therefore, will not contravene the NDAA 2000 activities considered inappropriate and will not have

⁴⁸ "National Defense Authorization Act for Fiscal Year 2000," Public Law 106-65, 106th Congress.

⁴⁹ The White House, "NSDD – 189, National Policy on the Transfer of Scientific, Technical, and Engineering Information," September 21, 1985, available at <<http://www.aau.edu/research/ITAR-NSDD189.html>>

⁵⁰ National Research Council of the National Academies, *Assessment of Department of Defense Basic Research* (Washington, DC: The National Academies Press, 2005).

military implications. Any proposed engagement in fundamental research with the Chinese, by its very nature, would not involve joint warfighting experiments, military-related technology transfer, or access to a DOD laboratory. Fundamental research does not fall under ITAR or export control regulations because it does not relate to any sale, transfer, or proposal to sell or transfer defense articles or defense services. Constructive basic research collaboration with China should not include research in any sensitive technology areas, such as nuclear research, space technologies, chemical and biological weapons research, and directed energy technologies.

Recommendations for Constructive Engagement

The potential for China to become a world-class player in S&T is evident from the growth they have achieved in S&T in the past decade. To remain competitive and on the cutting edge, it is important for the United States to develop an S&T collaborative relationship with China in fundamental research. Engaging in S&T cooperation will not only allow DOD to establish important relationships for future cooperation, but also help us to avoid technological surprises that could put U.S. national security at risk.

Engaging in collaborative fundamental research with China will not contravene the NDAA 2000 prohibited activities and will not have military implications

Collaborating with China in scientific research will lead to better understanding of their S&T capabilities, giving us the ability to identify and capitalize on emerging trends and technologies to leverage foreign resources and capabilities in both the short- and long-term, which are beneficial to the DOD. The approach to increased S&T collaboration with China in fundamental research

should involve a phased strategy and continual assessment of the relationship.

The United States-Hong Kong Policy Act of 1992 “establishes the authority of the U.S. government to treat Hong Kong as a non-sovereign entity distinct from China for purposes of U.S. domestic law based on the principles in the 1984 Sino-British Joint Declaration.”⁵¹ Consistent with the act, two separate engagement strategies could be developed, one for Hong Kong and one for mainland China.

Engagement between the DOD S&T communities and the Chinese academic community has been limited at best. DOD’s science engagement has typically involved attendance at conferences and symposia in China, and rare site visits to leading Chinese universities conducting fundamental research. The first stage of collaboration, therefore, could involve increased participation of DOD scientists in workshops and conferences in China.

Lack of transparency and understanding of the current approval process, however, has led to fewer scientists requesting permission to travel to China. Increasing transparency of the approval process will encourage more DOD scientists to request approval to engage with the Chinese in areas of benefit to the DOD.

⁵¹ State Department announcement of signing and text of the act, available at <http://usinfo.state.gov/eap/east_asia_pacific/china/china_hong_kong/hong_kong_policy_act.html>.

It would be beneficial to encourage scientific program managers to attend conferences and site visits when the increased engagement begins. If DOD scientific program managers have firsthand knowledge of Chinese capabilities, then they will be able to match Chinese scientists with Service research scientists to maximize the benefits of scientific collaboration.

DOD scientists also should be encouraged to visit leading S&T universities in China to determine the type and quality of research being undertaken and where DOD can benefit from collaborative activities. Site visits to the top universities also will facilitate the development of relationships and scientist-to-scientist collaboration between American and Chinese scientists.

DOD should co-sponsor or provide financial support for foreign technical conferences and workshops. The goals of providing this sponsorship are to expand opportunities for the presentation and publication of international research and increase access of U.S. scientists to cutting-edge S&T. Sponsoring a limited number of small research or seed projects with Chinese academics in key scientific areas would help demonstrate U.S. commitment to scientific collaboration. These activities will directly benefit the United States by providing us an ability to assess the level of scientific sophistication in China, establish important relationships for future cooperation, and learn new scientific techniques.

DOD should support short-term academic personnel exchanges with China, such as the Air Force Windows on Science Program. These programs sponsor visits by distinguished foreign scientific and technological personnel. Academic visitors also could attend technical conferences in the United States.

To facilitate dialogue and potential collaboration with Chinese academics, it would be very beneficial for the DOD to open a liaison office in China. The establishment of such an office would signal a commitment to engagement with Chinese academic institutions and would ease access to China's top S&T universities. The office could be based at or near the U.S. Embassy and staffed by Service representatives, as is done in international liaison offices in Argentina, Australia, Canada, Chile, France, Germany, Japan, Singapore, and the United Kingdom. The liaison scientists would provide direct interchange with members of the scientific and engineering communities and encourage the establishment of beneficial relationships between DOD scientists and engineers and their Chinese counterparts. Creating these relationships would allow DOD to not only identify world class S&T being undertaken in Chinese universities, but also create the opportunities for collaboration that supports DOD basic research objectives through discoveries of emerging foreign science.

After a year of constructive engagement, the program can be evaluated and additional types and levels of engagement could be approved.

Potential Areas for Collaboration

Because there are so many S&T doctoral students and academics in China, the country benefits greatly by being able to approach S&T problems in different ways, working on multiple approaches at one time. China has been investing heavily in S&T and, while there are currently a few areas where they have achieved world-class stature, it is very likely that in the next 15 years they will be world class in many areas of the life and physical sciences. In some key technology areas of high importance to DOD, they will most likely surpass the United States. Some areas in which China is advancing rapidly are:

- materials science, such as metamaterials and catalysis
- molecular reaction dynamics
- energetics
- nanotechnology
- biotechnology
- brain and cognitive sciences
- ocean sciences
- information technology
- energy and power technology
- alternate and sustainable fuel technology

This list is not comprehensive. It must be assumed that new areas for fruitful collaboration will emerge as DOD scientists explore S&T opportunities in China. The process is just beginning.

Findings and Recommendations

China is a world economic power and is rapidly becoming a world leader in S&T. China has committed to an ambitious strategy to increase its investments in S&T and in a workforce capable of making it a world class center for technological innovation that will drive its future economic and national security.

Recent visits to top Chinese academic institutions with strong S&T research programs demonstrated that they are attracting a cadre of excellent researchers trained in the top universities around the world. Indeed, many of the S&T leaders at these institutions, from presidents to department chairs to research institute directors, come from top U.S. universities where they maintain joint appointments. In addition, they are establishing research collaborations with top scientists around the world. Many are very interested in establishing fundamental research collaborations with U.S. scientists, including those from DOD.

It is in the long-term interest of DOD to proactively seek out opportunities to engage in fundamental scientific collaborations with the top academic institutions in China. Through such collaborations we will learn new scientific techniques and strategies, avoid technological surprise, and develop beneficial working relationships that will enhance our economic and national security.

Recommendations

We offer three straightforward recommendations on how to get started:

1. The Office of the Secretary of Defense for Acquisition, Technology and Logistics [OSD(AT&L)] should encourage DOD and component fundamental research scientists to engage in collaborative fundamental research with top Chinese academic research scientists in scientific areas that will contribute to the DOD Research & Engineering Strategic Plan.
2. The Office of the Secretary of Defense for Policy [OSD(P)] should develop a clear, streamlined, and well-publicized process for OSD and Component approval for fundamental research scientists to visit Chinese academic institutions and to attend S&T conferences in China.
3. OSD(ATL), working with OSD(P) and the Services, should develop a phased strategy for constructive engagement in fundamental research with Chinese academic institutions. Specific recommendations were elaborated on in the previous section of this paper.